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NUCLEAR CASUALTY DATA SUMMARY

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29 August 1980

Final Report for Period 16 November 1978—29 August 1980

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is an unclassified, comprehensive, and brief summary of casualty data developed by Dikewood from Japanese and Texas City disaster (ammonium-nitrate explosion in a docked ship) data. The data contained in the report were obtained from previously published Dikewood reports which received limited circulation. In this report, data pertinent to the assessment of personnel casualties (both mortality and injury) caused by detonation of a nuclear weapon are presented. Japanese nuclear-casualty data are presented

20. ABSTRACT (Continued)

for both Hiroshima and Nagasaki in Part I of the report, while Texas City disaster casualty data are given in Part II. All casualty data are presented in a consistent, compatible manner to facilitate comparison and applicability of the data. Both the Japanese and Texas City casualty data are subdivided by shielding category. Japanese total injury data are further delineated by the nuclear weapon effect causing the injury (i.e., blast, prompt-thermal radiation, or initial-nuclear radiation). The casualty data contained in this report have wider applicability than just to the particular circumstances which existed in the cities at the time.. In addition, the report contains pertinent nuclear weapon output and parameter data for Hiroshima and Nagasaki, as well as explosion data for the Texas City detonation.

PREFACE

The author wishes to acknowledge the effort, support, and guidance contributed by Mr. L. Wayne Davis of The Dikewood Corporation in the compilation of the data summarized in this report. The support and guidance of Mr. Sheldon Levin of the Armed Forces Radiobiology Research Institute (AFRRI) was also greatly appreciated.

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INTRODUCTION AND SUMMARY

Several published Dikewood reports (DC-FR-1028 (Reference 1), DC-FR-1054 (Reference 2), DC-FR-1060 (Reference 3), DC-FR-1041 (Reference 8), DC-FR-1070 (Reference 9), and DC-FR-1211 (Reference 10) of limited distribution contain considerable data pertinent to the determination of casualties resulting from a nuclear weapon detonation. Although much of these data were derived from analyses of the nuclear attacks on Japan at the end of World War II, their applicability extends far beyond the Japanese experience. The data presented in this report were developed by Dikewood over a ten-year period of extensive analysis of the raw data obtained from the Hiroshima and Nagasaki nuclear attacks on Japan and the Texas City disaster which occurred in April, 1947. This report collects unclassified casualty data applicable to a nuclear detonation into a single report.

The principal objective of this report was to collect the casualty data pertinent to nuclear-casualty assessments into a single concise report. Consequently, the majority of the report consists of graphical and related tabular data taken from previously published Dikewood reports, together with brief discussions of these data. Additional detail can be obtained from the original reports as required. The detailed initial-nuclear-radiation casualty results obtained from the Dikewood analysis of the Japanese data performed for the Armed Forces Radiobiology Research Institute under Contract No. DNA 001-79-C-0025 are not included in this report. These data are contained in Reference 7.

This report is separated into two parts. The first part is concerned only with the data obtained from the Japanese events. The second part presents the data derived from analysis of the Texas City disaster. Each part is essentially a complete report within itself although the data are presented in a compatible manner so that data from one part may be directly compared with data from the other part, provided the data are suitably scaled using applicable scaling techniques.

The Japanese nuclear-casualty data contains casualties attributable to all three prompt-weapon effects present in a nuclear detonation (i.e., initial-nuclear radiation, blast, and prompt-thermal effects). Pertinent nuclear weapon outputs and parameters are given for both Hiroshima and Nagasaki. The raw data sources and the results of the data analysis are briefly delineated. Although the casualty data presented in Part II are not based on a nuclear explosion, the blast data are of interest. Only blast casualties are given in Part II. The pertinent explosion parameters are included together with the raw data sources and the results of the data analysis.

Each part contains an introduction which outlines its content and presents pertinent introductory material especially regarding the detonation parameters and data sources. A conclusions and recommendations discussion concludes each part. These discussions briefly summarize the pertinent characteristics of the data contained within that part of the report. A general summary is not presented since the conclusions and recommendations discussions in each part adequately serve this purpose.

PART I

JAPANESE CASUALTY DATA

CHAPTER 1

INTRODUCTION

1-1 ORIGIN OF DATA SOURCES

The two nuclear weapons detonated over Japan at the end of World War II caused extensive property damage and casualties in both Hiroshima and Nagasaki. This section is concerned with general characteristics of these two events, the subsequent collection of the casualty data, and the analysis of these data by Dikewood.

1-1.1 Relevant Data for Both Cities

The topography and meteorological conditions in the two cities were quite different and any analysis of casualty data must be cognizant of these factors. Hiroshima was located on a delta at the mouth of a large river (the Ota) emptying into the ocean. Consequently, the city was located almost entirely on level ground. The weather was clear with essentially no wind. The gun-type nuclear device was detonated with a nuclear yield of about 12.5 KT at about 8:15 A.M., August 6, 1945.

In Nagasaki the imposion-type nuclear weapon was detonated with a nuclear yield of about 22 KT in a river valley facing the ocean between two ranges of hills over hilly terrain. At the time of the burst (about 11:00 A.M. on August 9, 1945), the weather conditions were somewhat unsettled; a cold front was approaching from the northwest, and the sky was partly cloudy with some industrial haze and light winds in the area.

1-1.2 Data Sources

Almost immediately after each detonation the Japanese initiated efforts at collecting damage and casualty data. During

September and October, United States personnel arrived since the war had ended on August 15, 1945. These personnel coordinated and participated in the collection of data for both casualties and damage. Most of the original survey data were collected within a few months after the detonations by the AFIP then called Army Institute of Pathology. Additional data were obtained from printed reports and other US sources.

1-1.3 Dikewood Data Analysis

Dikewood analyzed the data available from the two surveys discussed above. The original effort (Reference 2) consisted of coding and recording the available data in a form suitable for computer analysis and the development of nuclear-casualty curves using computer techniques. A subsequent, more detailed, analysis effort (see Appendix A of Reference 3) at Dikewood resulted in revision of some of the original casualty curves. This analysis also resulted in the development of nuclear-casualty curves by shielding category, as well as the methodology for scaling them to high yields. Other Dikewood analyses utilizing these Japanese data produced casualty prediction models for high-yield nuclear weapons (see References 8 and 9) and injury response and medical treatment effectiveness evaluations of populations at risk (Reference 10).

The casualty data by shielding category given in this report are consistent with the shielding categories used in Reference 3. The shielding categories used in Hiroshima are as follows: seismic reinforced-concrete buildings (entire building), basements of seismic reinforced-concrete buildings, middle floors of seismic reinforced-concrete buildings, nonseismic reinforced-concrete buildings, light steel-frame buildings, vehicles (streetcars and trains), wood-frame commercial buildings, wood-frame dwellings, outside-shielded category (principally by wooden structures), and outside-unshielded category. Nagasaki shielding categories are as follows: miscellaneous underground shelters, seismic reinforced-concrete buildings (entire building), lower floors of seismic reinforced-concrete buildings, middle floors of seismic reinforced-concrete buildings, nonseismic reinforced-concrete buildings, light steel-frame buildings, wood-frame commercial buildings, wood-frame dwellings, outside-shielded category, and outside-unshielded category. The shielding categories differ slightly between the two cities due to differences in the shielding configurations of the populations in the two cities. Additional detail concerning definitions of these shielding categories and the distribution of the population among them are contained in References 2 and 3.

Nearly all of the data contained in this report have been taken from the two reports discussed above. These two Dikewood reports received limited distribution since parts of them were classified.

1-2 REPORT OBJECTIVES

The principal objective of this part of the report is to collect as much pertinent Japanese nuclear-casualty data as possible into a single concise report. Data are also presented relevant to blast and prompt-thermal casualties, as well as initial-nuclear casualties, principally in the form of graphical presentations with brief explanations containing references to the original reports for additional detail. This report does not contain any initial-nuclear-radiation injury results of the type concerned with specific injury symptom responses (for these data see Reference 7). Only the more general type of overall casualty data (i.e., mortality and injury) are given in this report.

1-3 ORGANIZATION

This part of the report is subdivided into five chapters. The next chapter after this introduction is concerned with the free-field weapon effects (initial-nuclear radiation, blast, and prompt-thermal radiation) which were present in Hiroshima and Nagasaki. The next chapter presents the mortality data for both cities. Chapter 4 gives the injury data for both cities, while the last chapter gives a brief summary of the conclusions and recommendations.

CHAPTER 2
FREE-FIELD WEAPON EFFECTS

2-1 BURST PARAMETERS

Table 1 presents the burst parameters (weapon yields, heights of burst, and hypocenter locations) and the initial-nuclear radiation data (gamma and neutron normalizing coefficients and associated relaxation lengths for both cities). Values used for the analyses performed in the source documents (References 2 and 3), as well as the currently accepted values, are both given in Table 1. As shown in Table 1, the hypocenters and heights of burst have been refined somewhat over the intervening years between the original Dikewood analyses and the present. However, the original values have been reused in this report for consistency since only relatively minor changes would result.

2-2 INITIAL-NUCLEAR RADIATION

The free-air initial-nuclear-radiation dose equations that are applicable in both cities utilize the parameters from Table 1. Although separate equations are given for calculation of the free-air gamma (Equation 1) and neutron (Equation 2) doses, both equations are of the same form and differ only in the parameter values used from Table 1 for each city. The total free-air initial-nuclear-radiation dose in each city is the sum of the gamma and neutron doses as determined from the use of the following equations.

Gamma dose equation: $$D_g = \frac{G_o\, e^{-R/L_g}}{R^2} \qquad (1)$$

Neutron dose equation: $$D_n = \frac{N_o\, e^{-R/L_n}}{R^2} \qquad (2)$$

where,

$$R = \sqrt{HOB^2 + HR^2} \qquad (3)$$

Table 1. Burst parameters and initial-nuclear-radiation data for Japan.

Parameter	Hiroshima		Nagasaki	
	Analysis[a]	Current[b]	Analysis[a]	Current[b]
Hypocenter East-West AMS Coordinate[c] (kiloyds)	744.281	744.298	1293.61	1293.624
Hypocenter North-South AMS Coordinate[c] (kiloyds)	1261.696	1261.707	1065.92	1065.936
Height of Burst (ft)	1870	1903	1640	1650
Burst Point Gamma Normalizing Coefficient G_o (rads-ft^2)	3.71×10^{11}	3.71×10^{11}	2.96×10^{11}	2.96×10^{11}
Burst Point Neutron Normalizing Coefficient N_o (rads-ft^2)	9.36×10^{11}	9.36×10^{11}	1.399×10^{11}	1.399×10^{11}
Gamma Relaxation Length L_g (ft)	820	820	1148	1148
Neutron Relaxation Length L_n (ft)	650	650	650	650

[a]Parameters used for analysis in References 2 and 3.

[b]Currently accepted item values as given in Reference 7.

[c]AMS is an abbreviation for the coordinate terminology used in the U.S. Army Map Service series L902, map number 138449 (September, 1946) for Hiroshima and 138353 (August, 1945) for Nagasaki.

and,

D_g = gamma dose (rads) at slant range R for a city,

D_n = neutron dose (rads) at slant range R for a city,

R = slant range (ft) from burst point,

G_o = burst point gamma normalizing coefficient (rads-ft^2) for a city from Table 1,

N_o = burst point neutron normalizing coefficient (rads-ft^2) for a city from Table 1,

L_g = gamma relaxation length (ft) for a city from Table 1,

L_n = neutron relaxation length (ft) for a city from Table 1,

HOB = height of burst (ft) for a city from Table 1, and

HR = horizontal range (ft) from the hypocenter for a city.

Equations 1 and 2 were used in combination with Equation 3 to calculate the initial gamma, neutron, and total (gamma plus neutron) free-air doses in each city as a function of horizontal range in feet. These calculated free-air doses are given in Figures 1 and 2, respectively, for Hiroshima and Nagasaki.

2-3 BLAST AND PROMPT-THERMAL RADIATION

Using data from Reference 2, the free-air blast (peak overpressure in psi) and prompt-thermal radiation (exposure in cal/cm^2) are also presented as a function of horizontal range (in feet) in Figures 3 and 4, respectively, for Hiroshima and Nagasaki. As discussed in Reference 2, the blast data were derived from <u>The Effects of Nuclear Weapons</u> (Reference 4) and the prompt-thermal exposure is based on the following equation given in Reference 2.

$$Q = \frac{f\,W\,\overline{T} \times 10^{12}}{4\pi R^2} \qquad (4)$$

where,

Q = prompt-thermal radiation exposure (cal/cm^2) at slant range R,

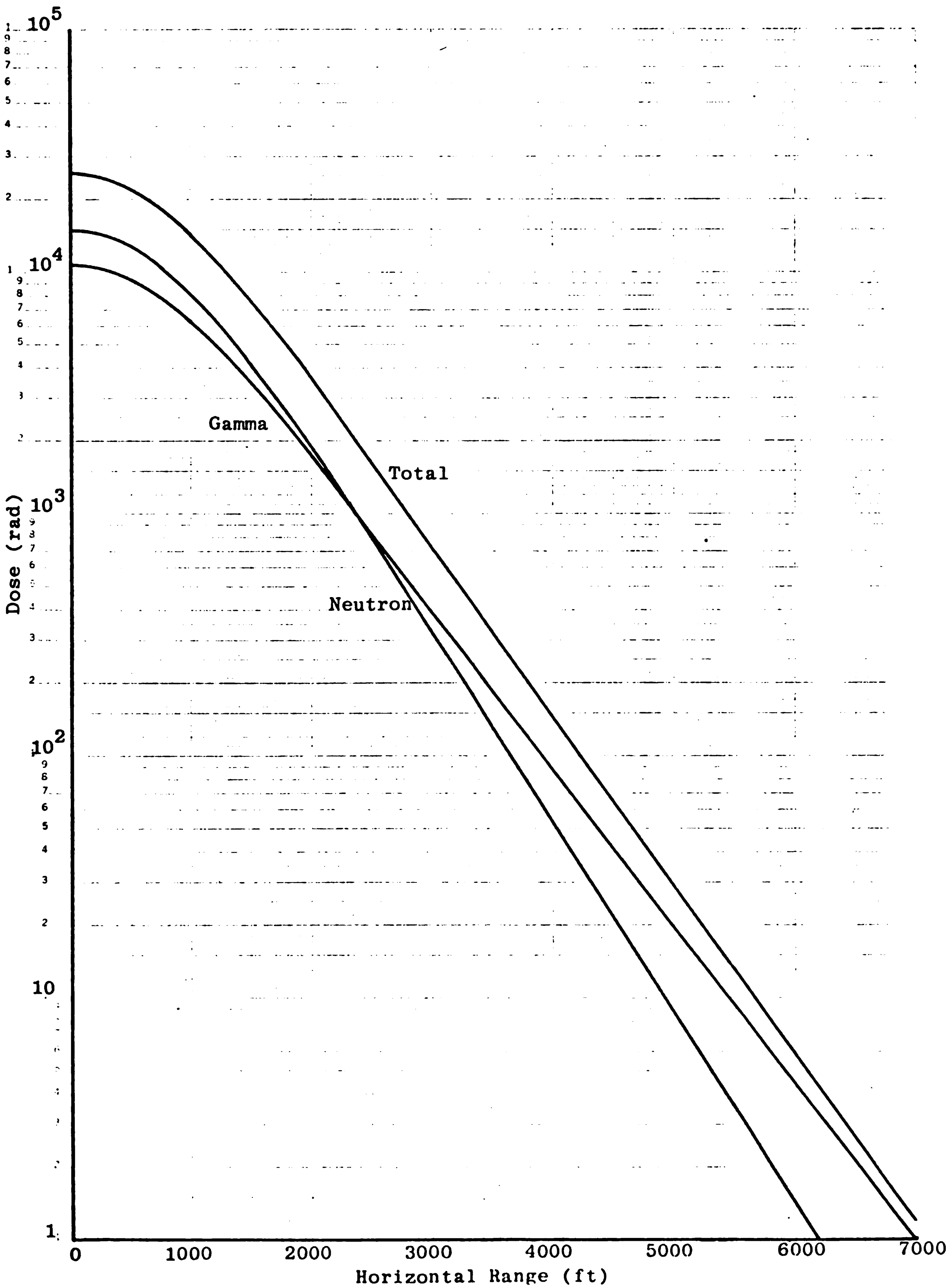

Figure 1. Free-air initial-nuclear radiation for Hiroshima.

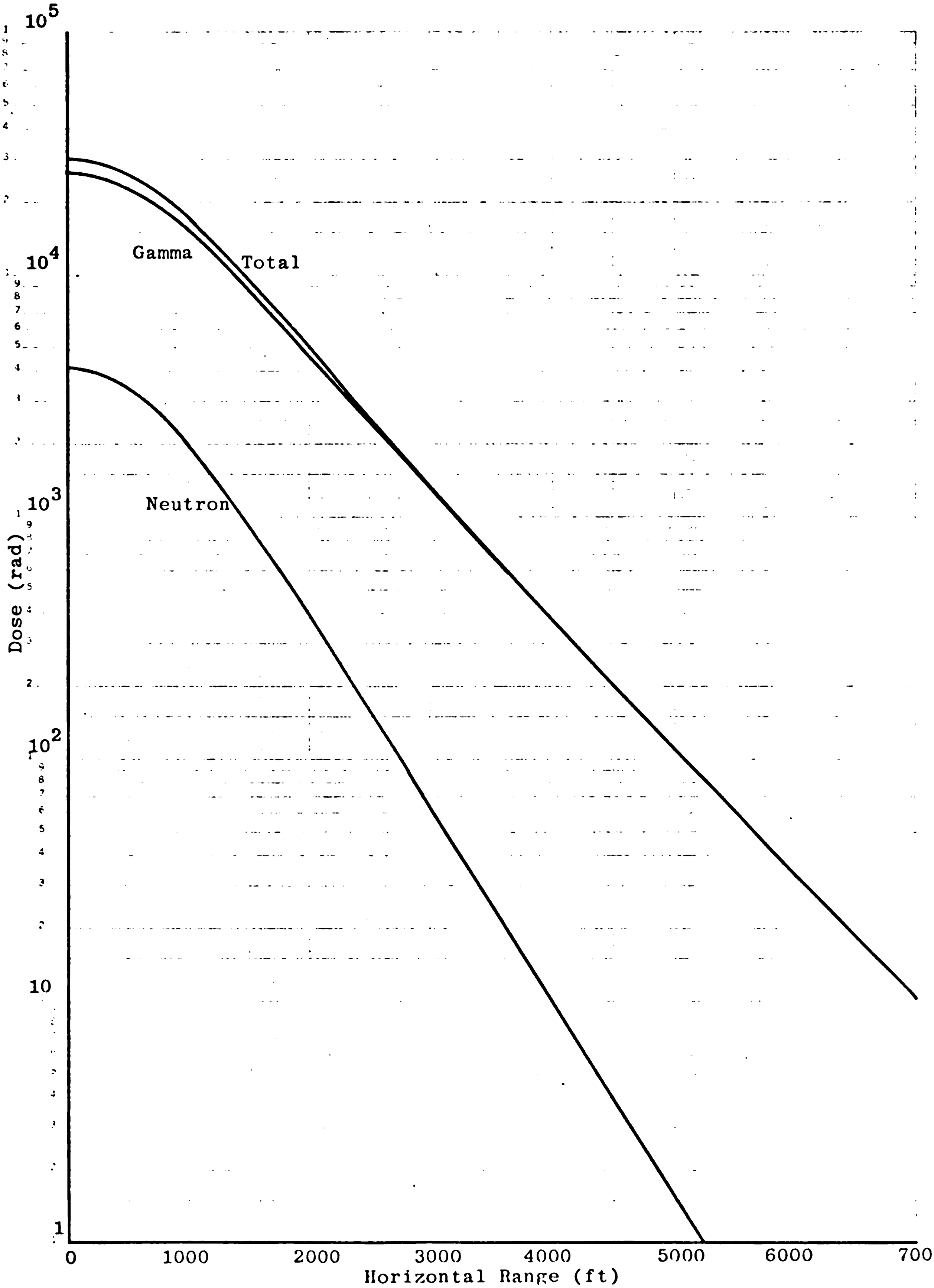

Figure 2. Free-air initial-nuclear radiation for Nagasaki.

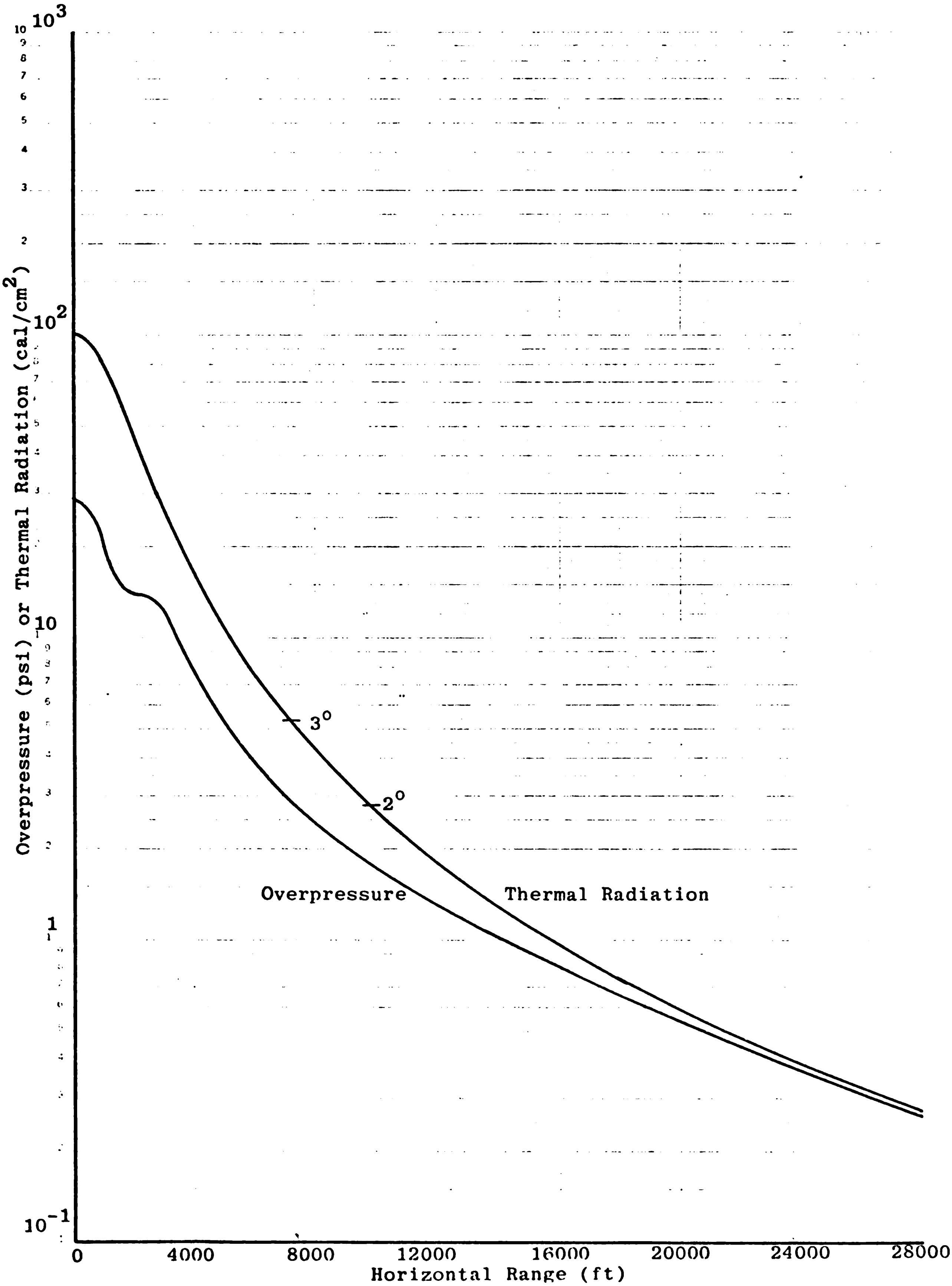

Figure 3. Free-air overpressure and prompt-thermal radiation for Hiroshima.

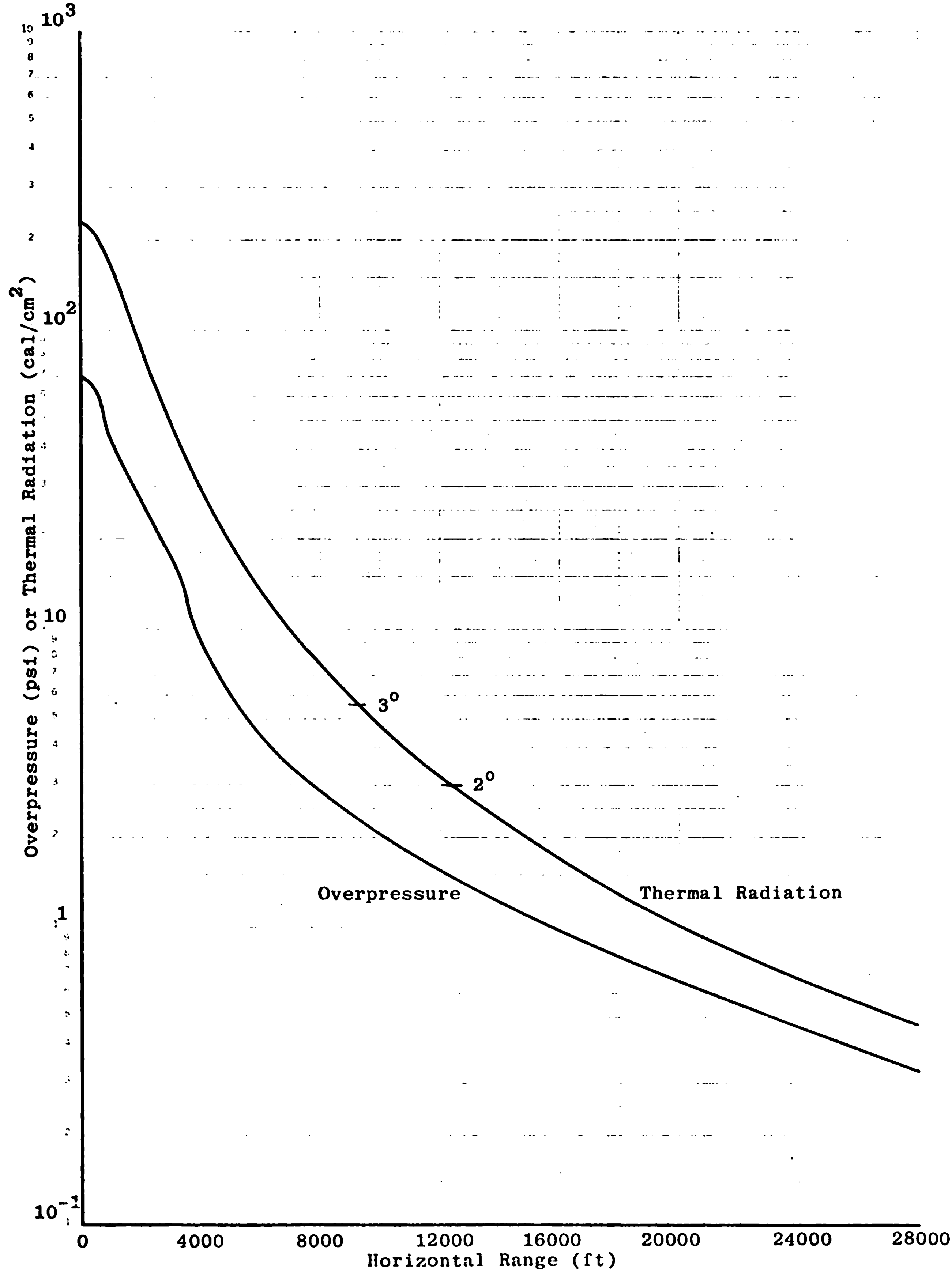

Figure 4. Free-air overpressure and prompt-thermal radiation for Nagasaki.

f = 0.38 = fraction of the total yield in the form of prompt-thermal radiation (Reference 5),

W = total yield (KT),

$\bar{T}$ = average atmospheric prompt-thermal transmissivity (Reference 6), and

R = slant range from burst point (cm).

The prompt-thermal curves in Figures 3 and 4 for Hiroshima and Nagasaki indicate the thermal exposure levels where second and third degree burns could be expected on directly exposed bare Japanese type skin. The prompt-thermal exposure levels for third-degree burns on bare skin are 5.3 and 5.6 cal/cm^2 for Hiroshima and Nagasaki, respectively. For second-degree burns the values are 2.8 and 3.0 cal/cm^2 for Hiroshima and Nagasaki, respectively (see Reference 2 for additional detail).

CHAPTER 3
MORTALITY

3-1 CALCULATED INITIAL-NUCLEAR-RADIATION MORTALITY

This discussion briefly describes the calculational procedure used to develop initial-nuclear-radiation mortality curves by shielding category which were useful in defining the associated total mortality curves in regions where Japanese survey data were unavailable or unreliable. As described in Appendix A of Reference 3, a statistical evaluation of the initial-nuclear-radiation protection factors by shielding category was performed using data obtained from the Japanese experience for Hiroshima and Nagasaki. The results of this analysis are contained in Tables 2 and 3 for Hiroshima and Nagasaki, respectively. These tables present the average (mean) initial-neutron and gamma protection factors by shielding category for each city. These tables also give the minimum and maximum protection factors by shielding category. These extremes are associated with one standard deviation below and above the mean, respectively. Figure 5, which gives the percent mortality versus nuclear exposure dose, was obtained from Reference 1.

The protection factors for Hiroshima (Table 2) and Nagasaki (Table 3) were combined with the respective free-air initial-radiation doses for Hiroshima (Figure 1) and Nagasaki (Figure 2) to determine the exposure dose by shielding category. The mortality data from Figure 5 was then used to define the mortality curves by shielding category for each city. It should be noted that the 100, 50, and 0 percent mortality points utilized the maximum, average, and minimum protection factors, respectively, as well as the estimated population configurations for each shielding category. For additional detail, see Appendix A of Reference 3. The resulting theoretical initial-nuclear mortality curves as a function of horizontal range (feet) by shielding category are presented in Figures 6 and 7 for Hiroshima and Nagasaki, respectively.

Table 2. Summary of initial-nuclear-radiation protection factors for Hiroshima.

Shielding Posture	Neutron Protection Factors			Gamma Protection Factors		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Seismic reinforced concrete (basements)	30.0	110.0	250.0	8.4	30.0	125.0
Seismic reinforced concrete (middle floors)	10.0	75.0	100.0	8.3	21.0	75.0
Seismic reinforced concrete (overall)	10.0	100.0	200.0	8.3	20.0	100.0
Nonseismic reinforced concrete	6.5	27.0	100.0	3.4	7.6	75.0
Light steel-frame industrial	2.5	3.5	4.0	1.5	2.3	2.7
Vehicles (primarily streetcars)	2.3	3.3	3.9	1.4	2.1	2.6
Wood-frame commercial	2.1	3.2	3.8	1.3	1.9	2.5
Wood-frame dwelling	2.0	2.9	3.7	1.3	1.8	2.4
Outside shielded (by light buildings)	2.1	2.9	3.8	1.3	1.8	2.4
Outside unshielded	1.0	1.0	1.0	1.0	1.0	1.0

Table 3. Summary of initial-nuclear-radiation protection factors for Nagasaki.

Shielding Posture	Neutron Protection Factors			Gamma Protection Factors		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Underground shelters	500.0	1000.0	5000.0	70.0	100.0	500.0
Seismic reinforced concrete (lower floors)	50.0	110.0	300.0	9.3	30.0	150.0
Seismic reinforced concrete (middle floors)	10.0	70.0	150.0	6.0	20.0	100.0
Seismic reinforced concrete (overall)	20.0	70.0	150.0	6.0	20.0	100.0
Nonseismic reinforced concrete	10.0	40.0	100.0	3.0	6.0	60.0
Light steel-frame industrial	3.6	4.5	5.0	2.0	2.9	3.3
Wood-frame commercial	2.3	3.8	4.5	1.5	2.4	3.1
Wood-frame dwelling	2.2	3.0	4.0	1.4	2.1	2.7
Outside shielded (by light buildings)	2.3	3.4	4.2	1.4	2.3	2.9
Outside unshielded	1.0	1.0	1.0	1.0	1.0	1.0

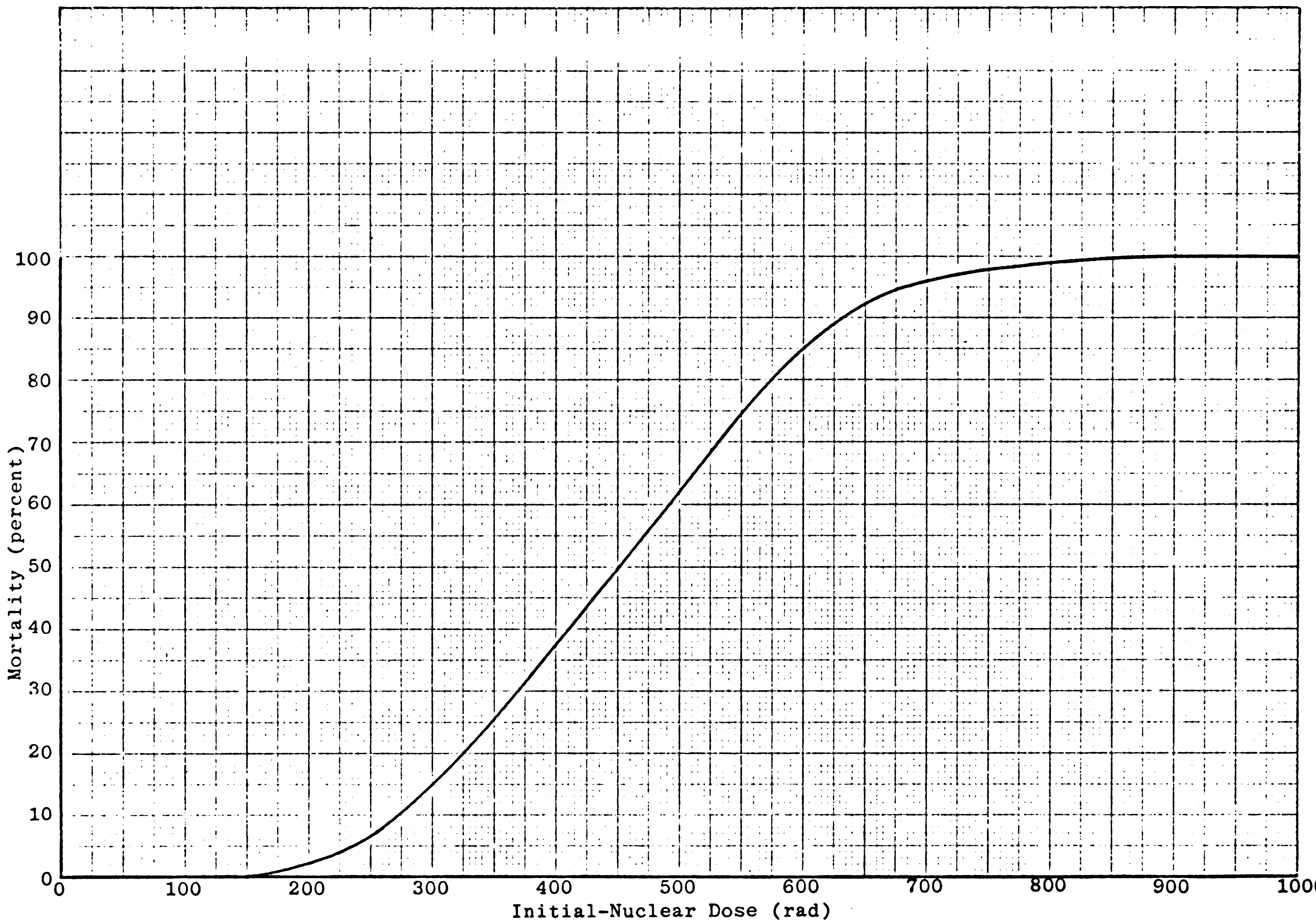

Figure 5. Initial-nuclear mortality versus delivered dose.

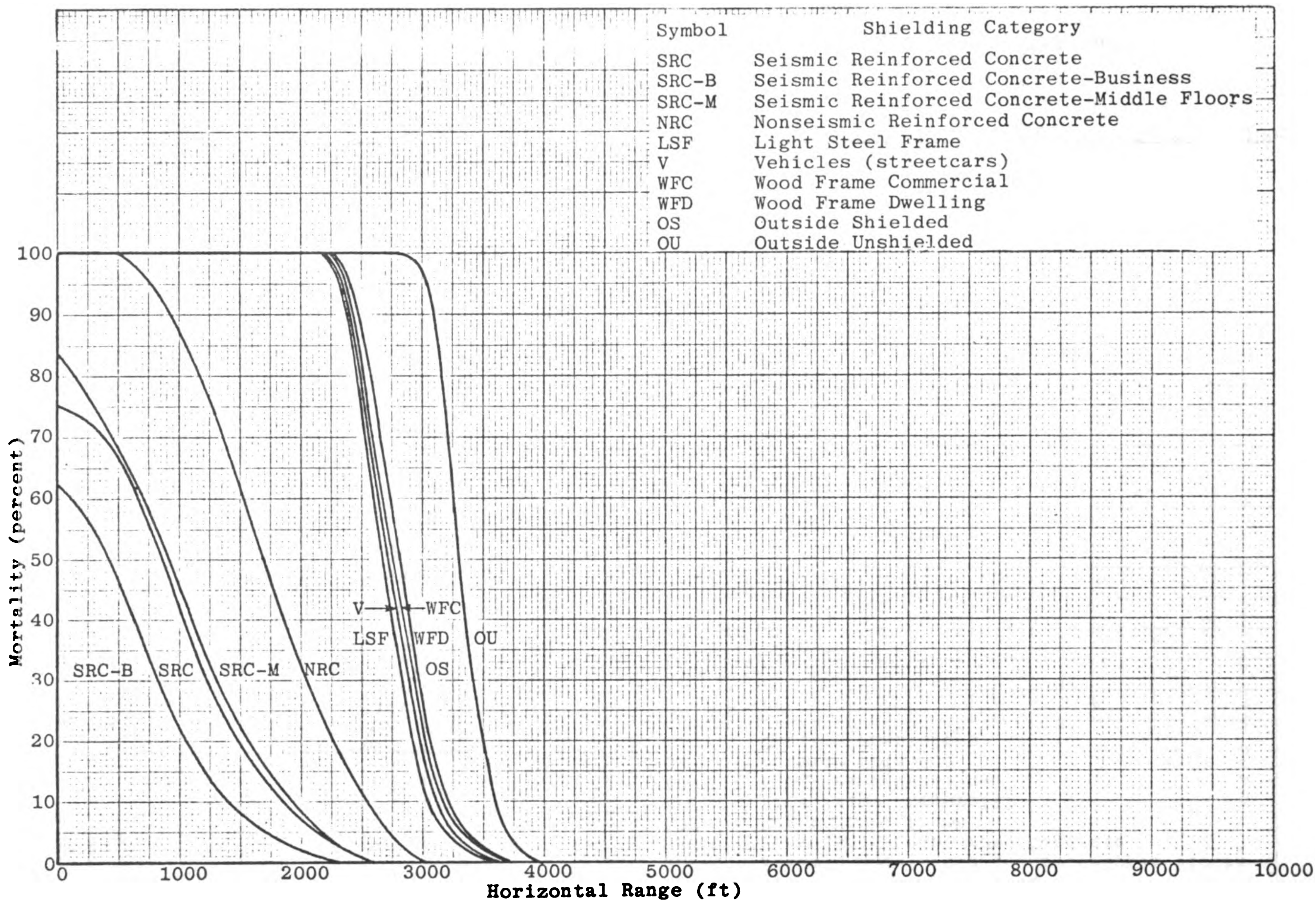

Figure 6. Theoretical initial-nuclear mortality curves for Hiroshima.

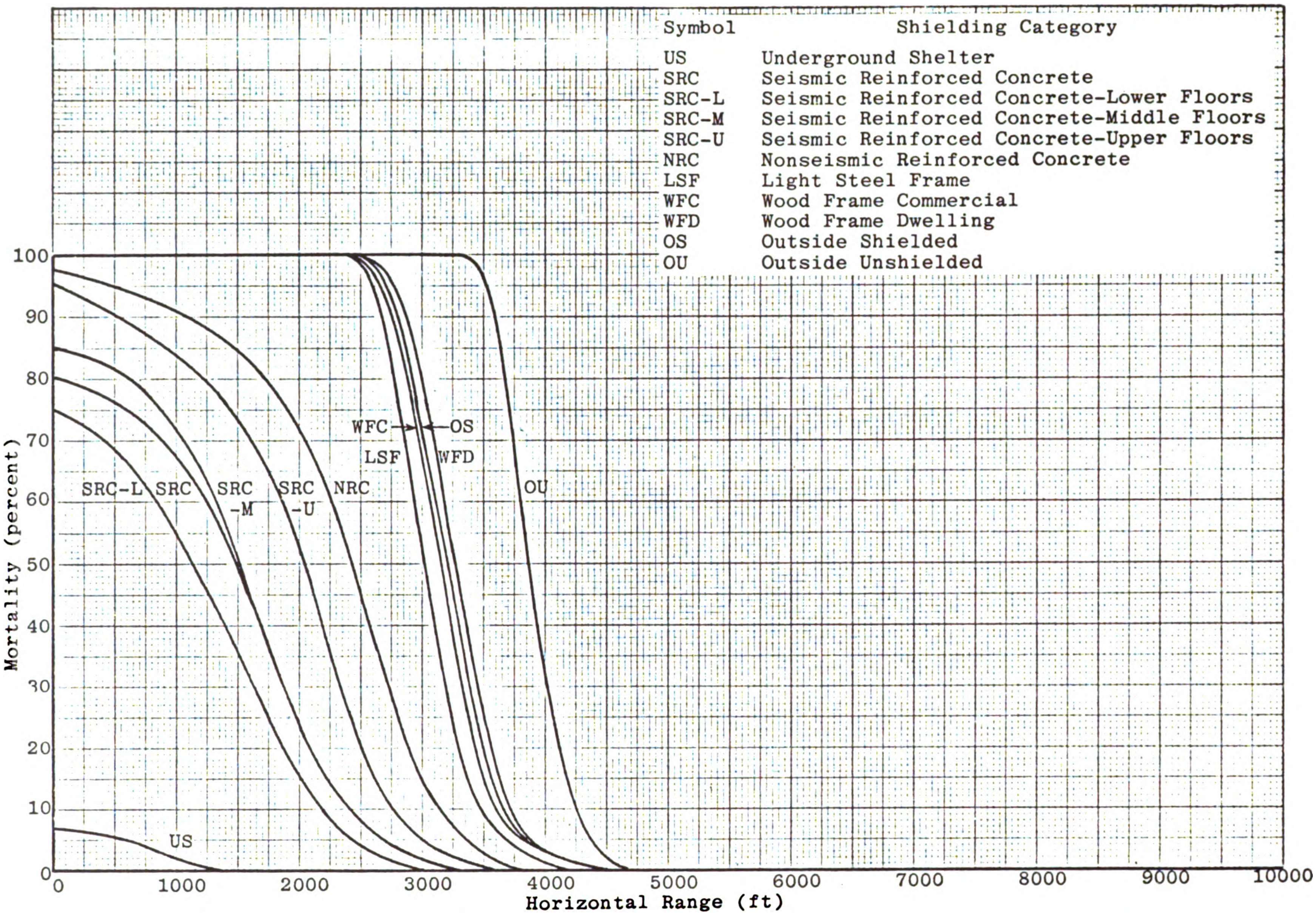

Figure 7. Theoretical initial-nuclear mortality curves for Nagasaki.

3-2 TOTAL MORTALITY DATA

The theoretical initial-nuclear mortality curves discussed above were then used in conjunction with the Japanese mortality data by shielding category (see Reference 2) to define the total mortality curves presented in Figures 8 and 9. (See Appendix A of Reference 3 for more detail.) Since the total mortality curves also influence other vital data (such as the total injury and killed-immediately data), it was essential that these mortality curves be accurately defined. Thus, this somewhat complex methodology was used to refine the total mortality curves given in Appendix A of Reference 3 from those given in Reference 2. Since each figure presents mortality data for all shielding categories, individual data points could not be included. However, as an example of the type of data obtainable from the Japanese data base, Figure 10 presents the mortality curve for wood-frame dwellings in Hiroshima complete with data points coded according to sample size.

3-3 PROMPT-THERMAL MORTALITY

Since conventional nuclear weapons emit large quantities of prompt-thermal radiation, prompt-thermal (flash burn) casualties are also important in nuclear weapon casualty assessments. The biologically damaging effects of prompt-thermal radiation from a nuclear weapon are a function of the thermal exposure level (cal/cm^2). Figure 11 presents prompt-thermal mortality for outside-unshielded persons (as obtained from Chapter 3 of Reference 3) as a function of prompt-thermal exposure in cal/cm^2 for a 12.5 KT surface burst. In this form, the data are readily scaled to other yields of interest. For additional scaling procedures for prompt-thermal casualties, reference should be made to Appendix D of Reference 3.

The relationship between mortality and percentage of the body area burned for second and third degree burns are given in Figure 12 for Nagasaki (no such data were available for Hiroshima)

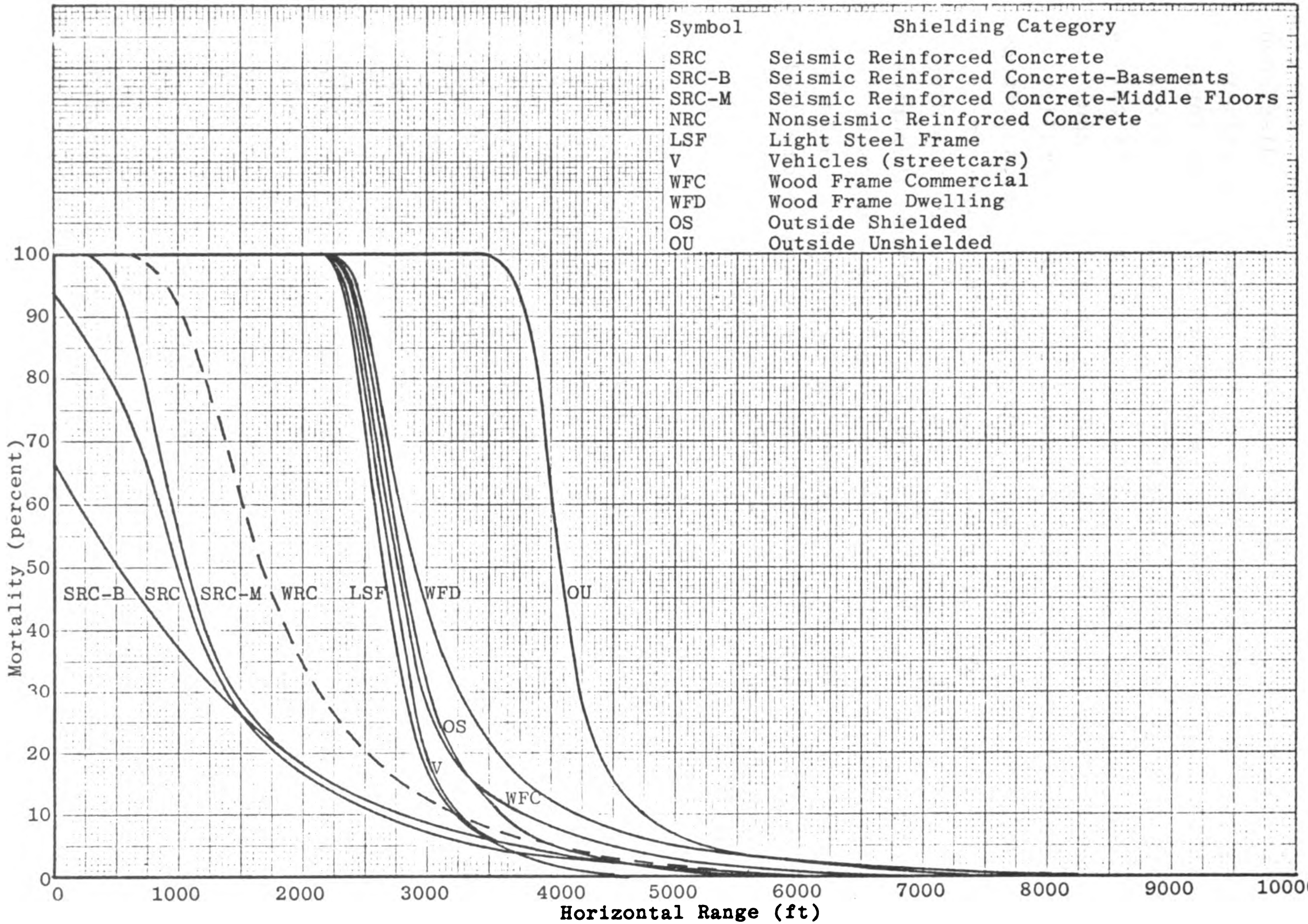

Figure 8. Total mortality curves for Hiroshima.

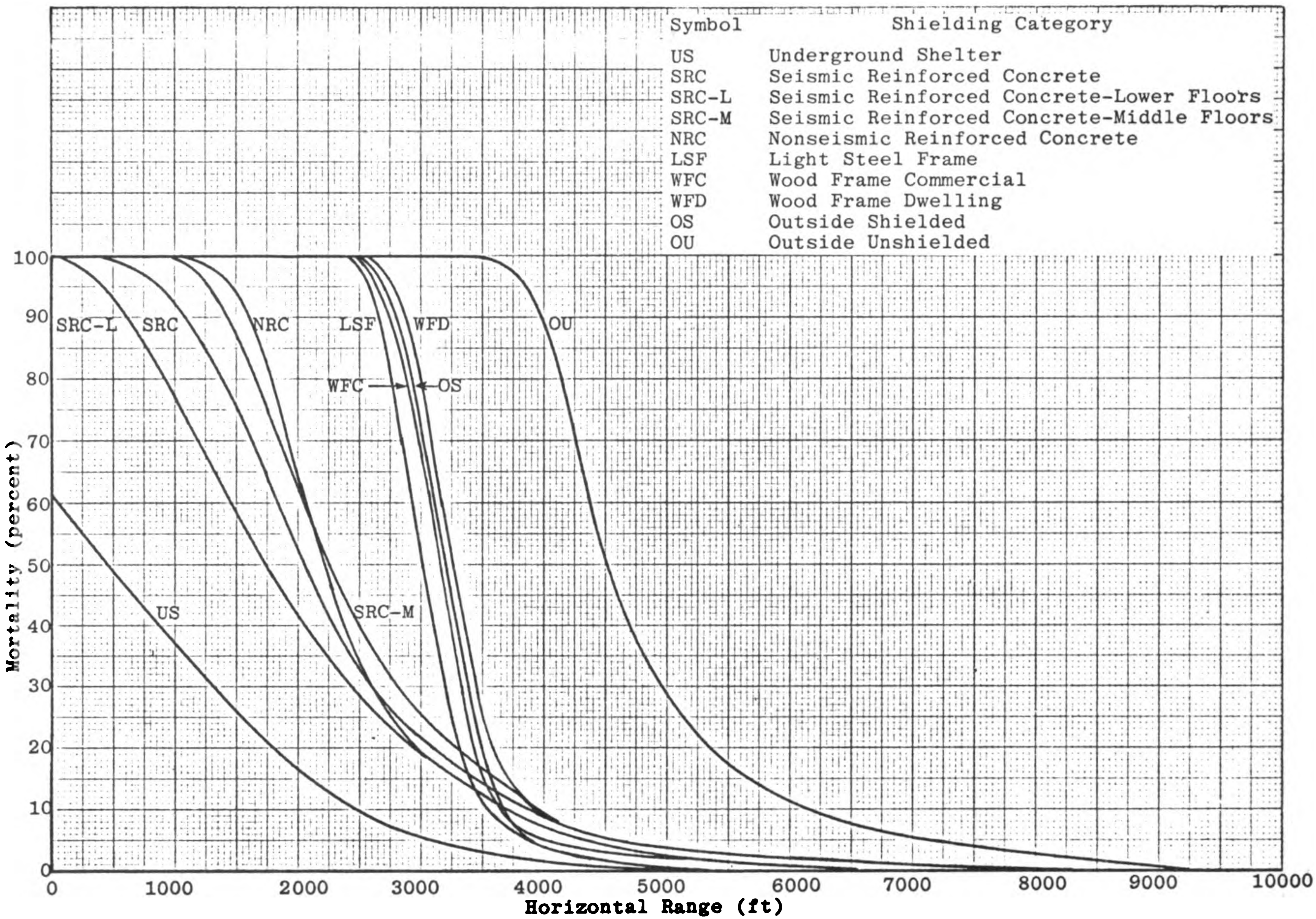

Figure 9. Total mortality curves for Nagasaki.

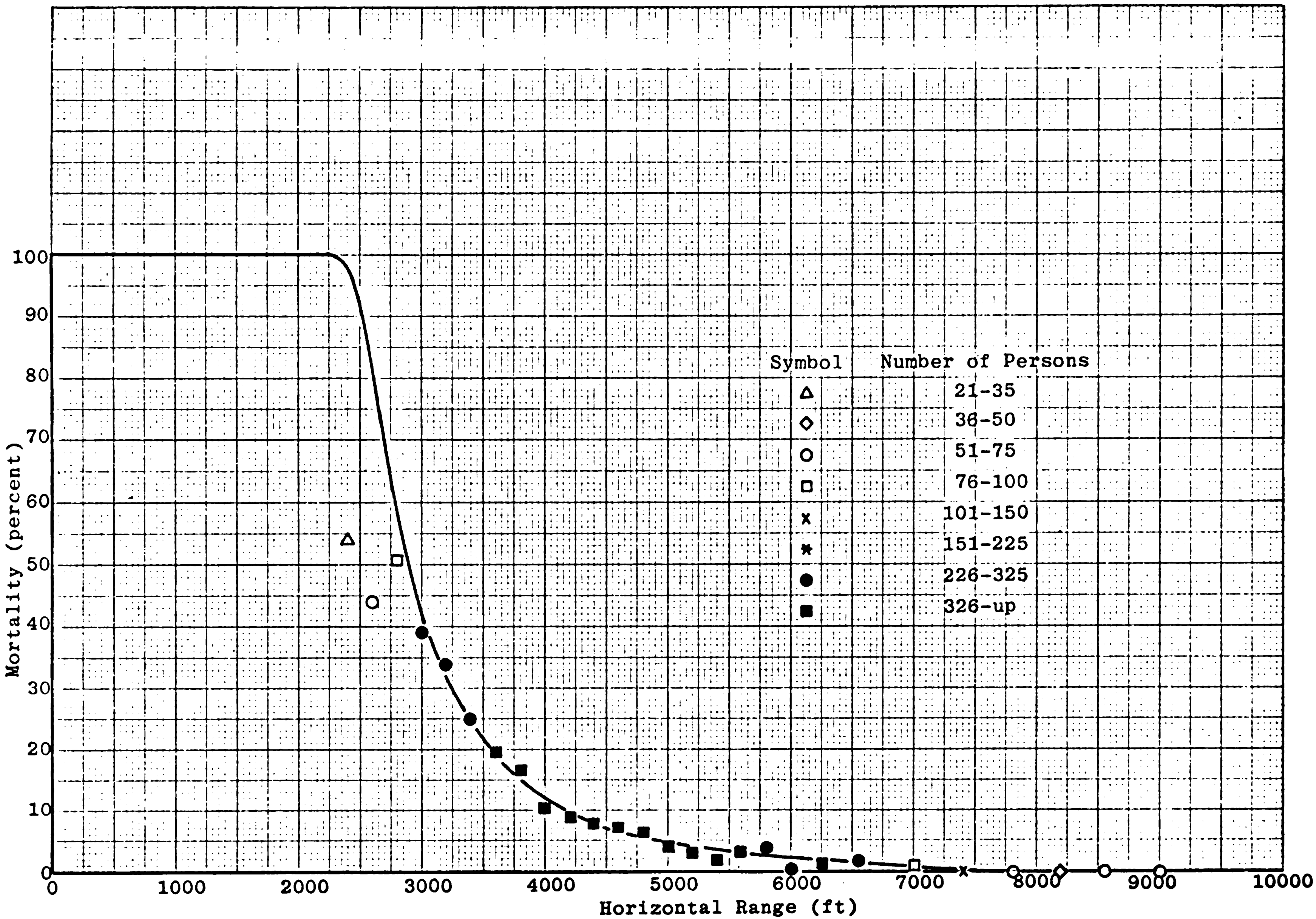

Figure 10. Hiroshima total mortality curve with data for wood-frame dwellings.

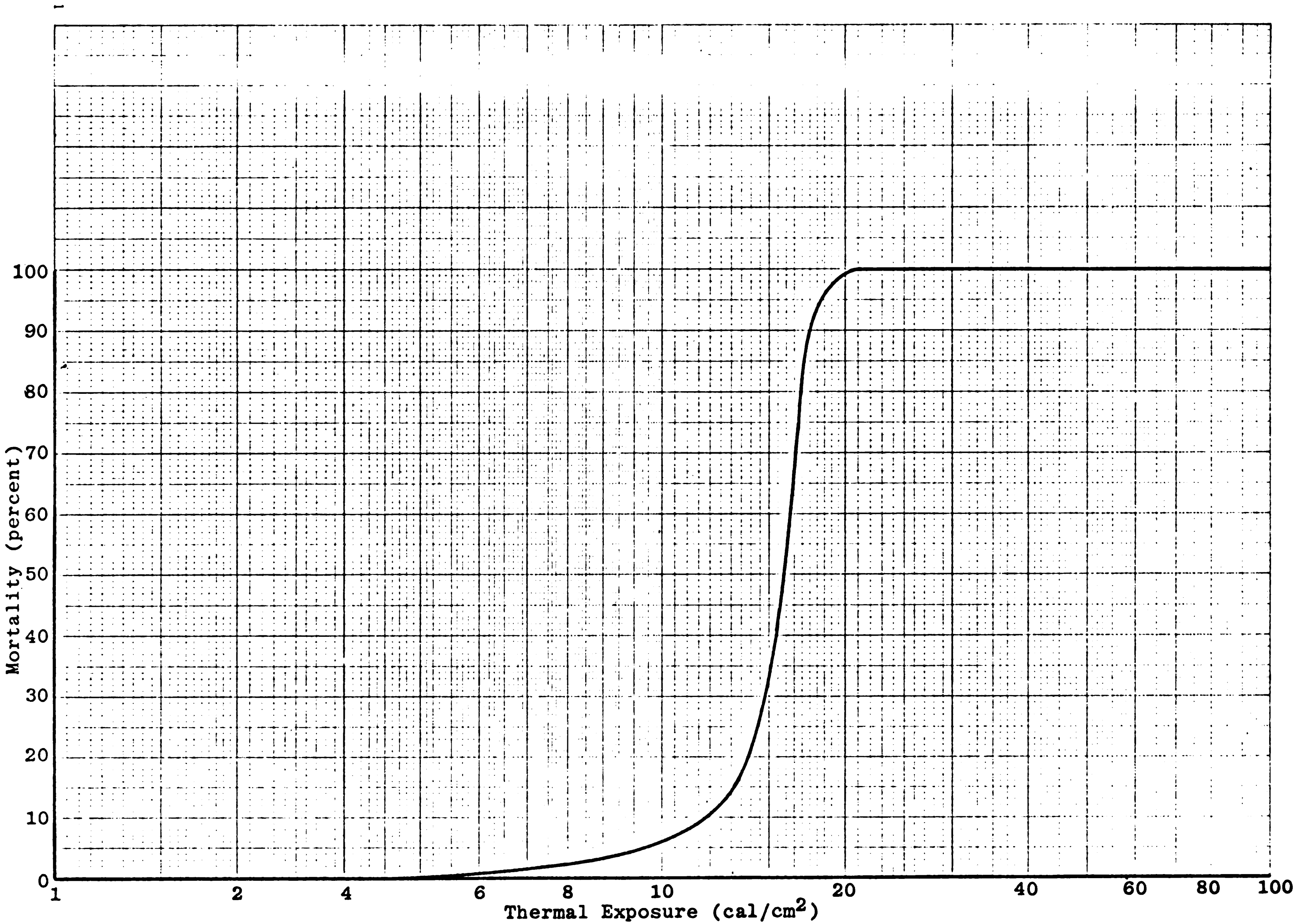

Figure 11. Prompt-thermal mortality curve for outside-unshielded persons (12.5 KT surface burst

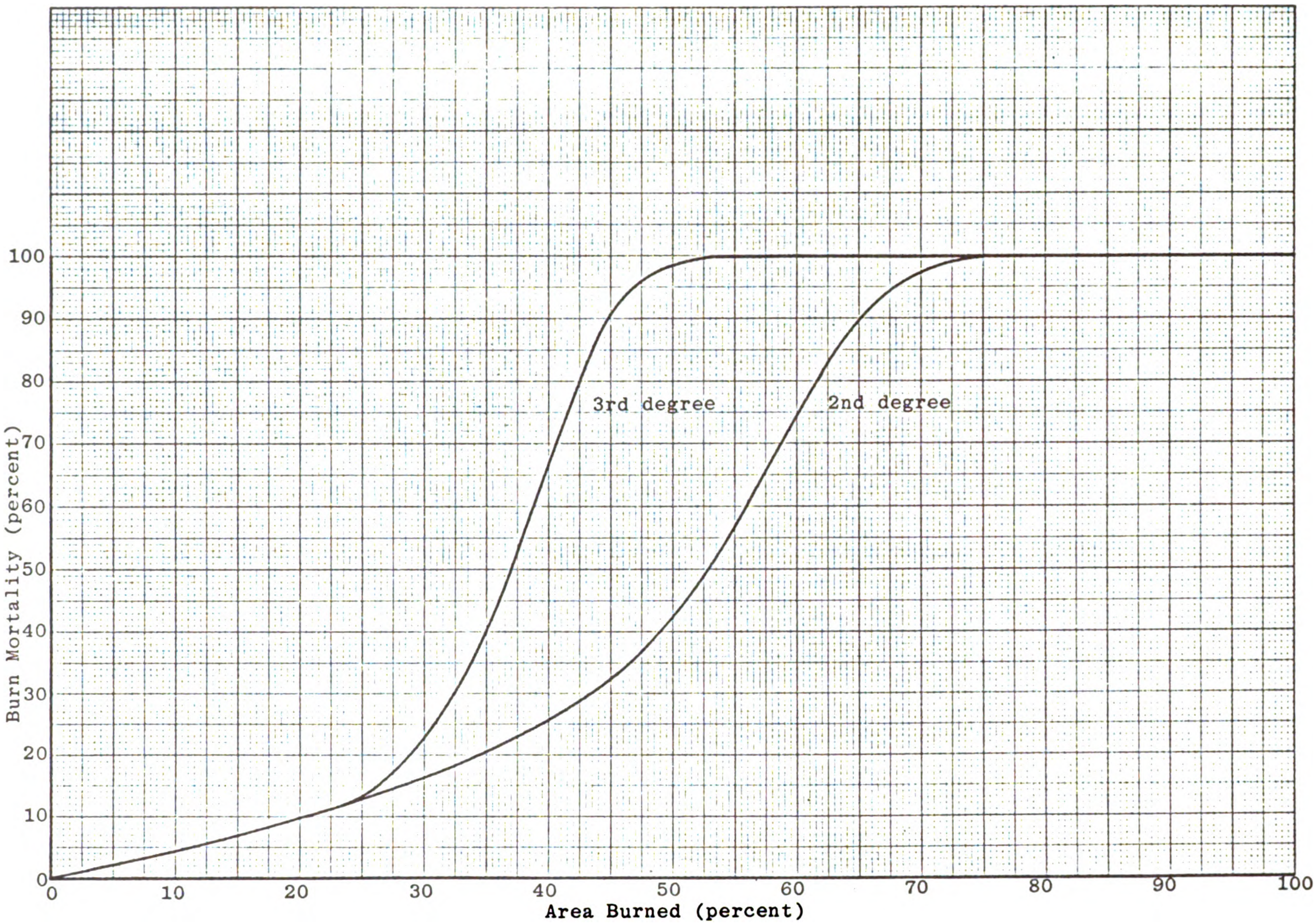

Figure 12. Burn mortality versus percent area burned for Nagasaki.

as taken from Reference 2. These data should be quite valuable in defining burn lethality versus burn severity for an exposed population receiving minimal medical care.

3-4 KILLED-IMMEDIATELY MORTALITY

Due to the lack of more precise information from the original survey data, the term "killed immediately" was defined by Dikewood to refer to persons who died on the day of the attack (August 6, 1945, in Hiroshima and August 9, 1945, in Nagasaki). For additional detail concerning the killed-immediately mortality data, consult Reference 2. The killed-immediately curves presented in Figures 13 and 14 for Hiroshima and Nagasaki, respectively, are the revised curves given in Reference 3. Only three shielding categories are contained in each of these figures due to limitations of the original data (see Reference 2).

3-5 TIME TO DEATH OF MORTALLY INJURED

The mortally injured percentage at a given horizontal range is basically defined as the difference between the total mortality and killed-immediately percentage values for a given shielding category. Since all persons who died on the day of the attack were included in the killed-immediately classification, mortally injured persons died after the first day. Consequently, the time-to-death curves for mortally injured persons all start at zero (day of burst) and the mortality percentage increases with time after the burst. Limitations on the obtainable data are discussed in detail in Reference 2. The time-to-death data from Reference 2 have been replotted for compatibility of form in Figures 15 and 16 for Hiroshima and Nagasaki, respectively. The number of shielding categories is somewhat restricted over those available for the total mortality curves due to the limited data available.

The time-to-death curves given in this report apply principally to the mortally injured in Hiroshima and Nagasaki, or similar situations, due to the quantity of initial-nuclear-radiation

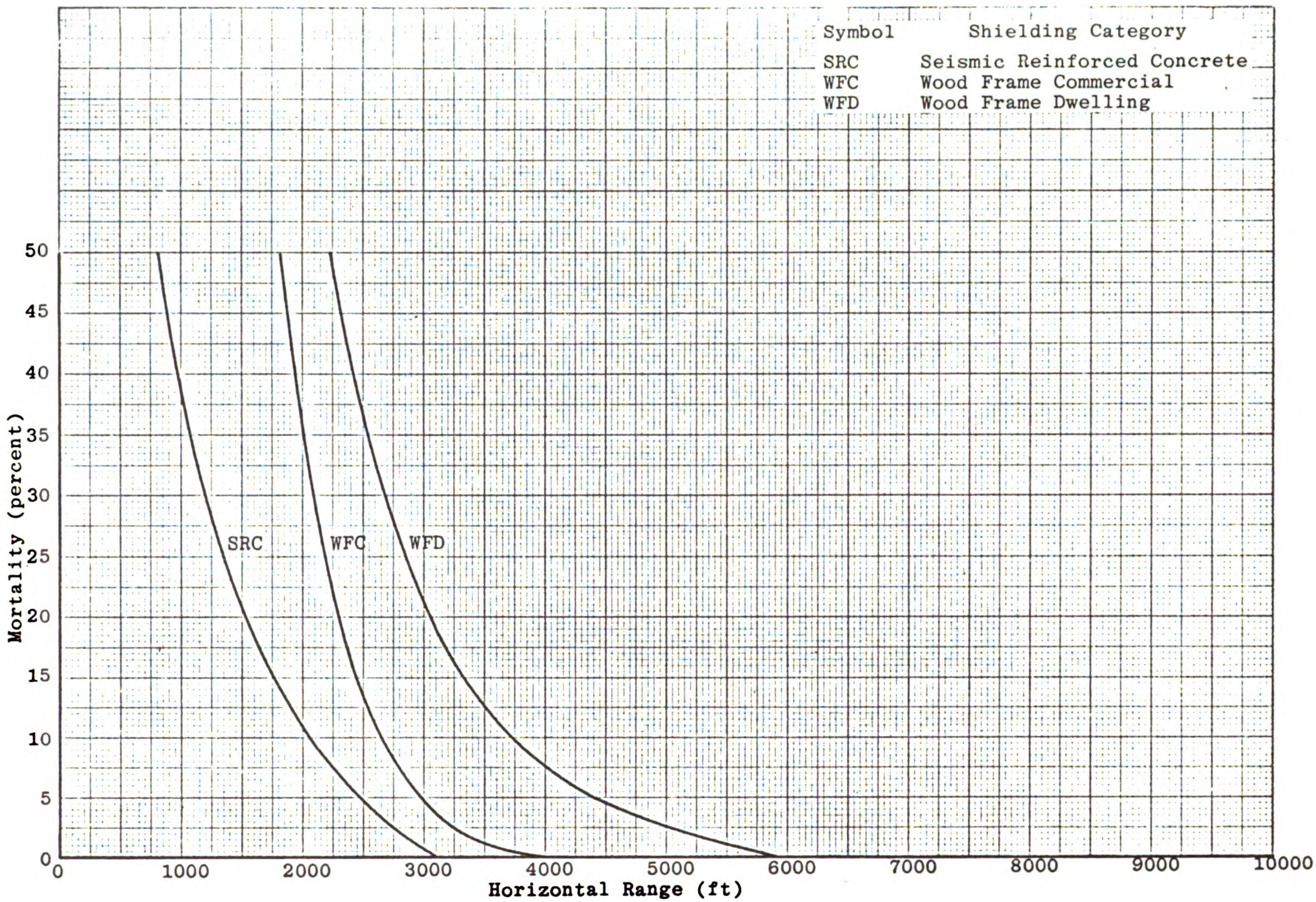

Figure 13. Killed-immediately curves for Hiroshima.

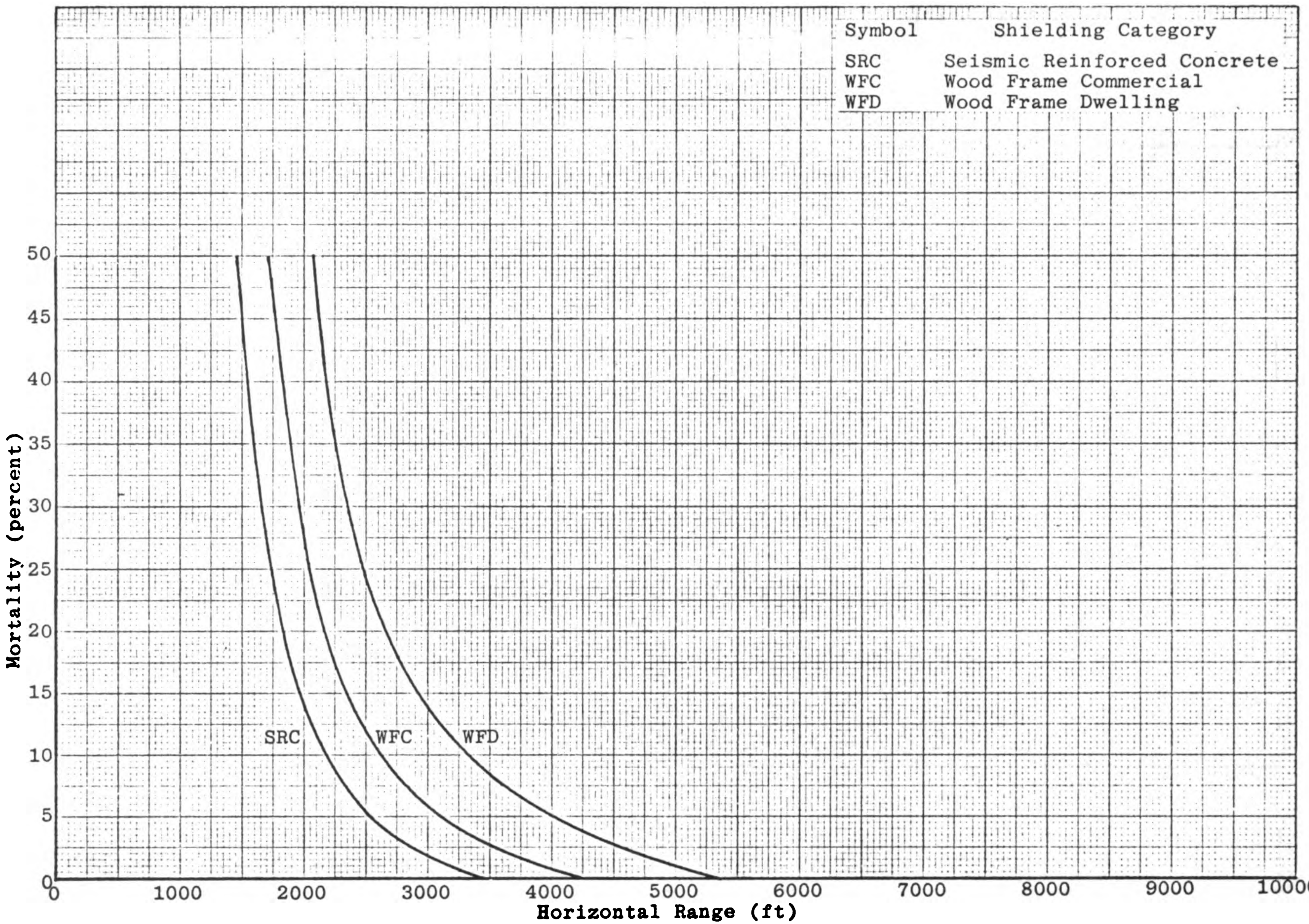

Figure 14. Killed-immediately curves for Nagasaki.

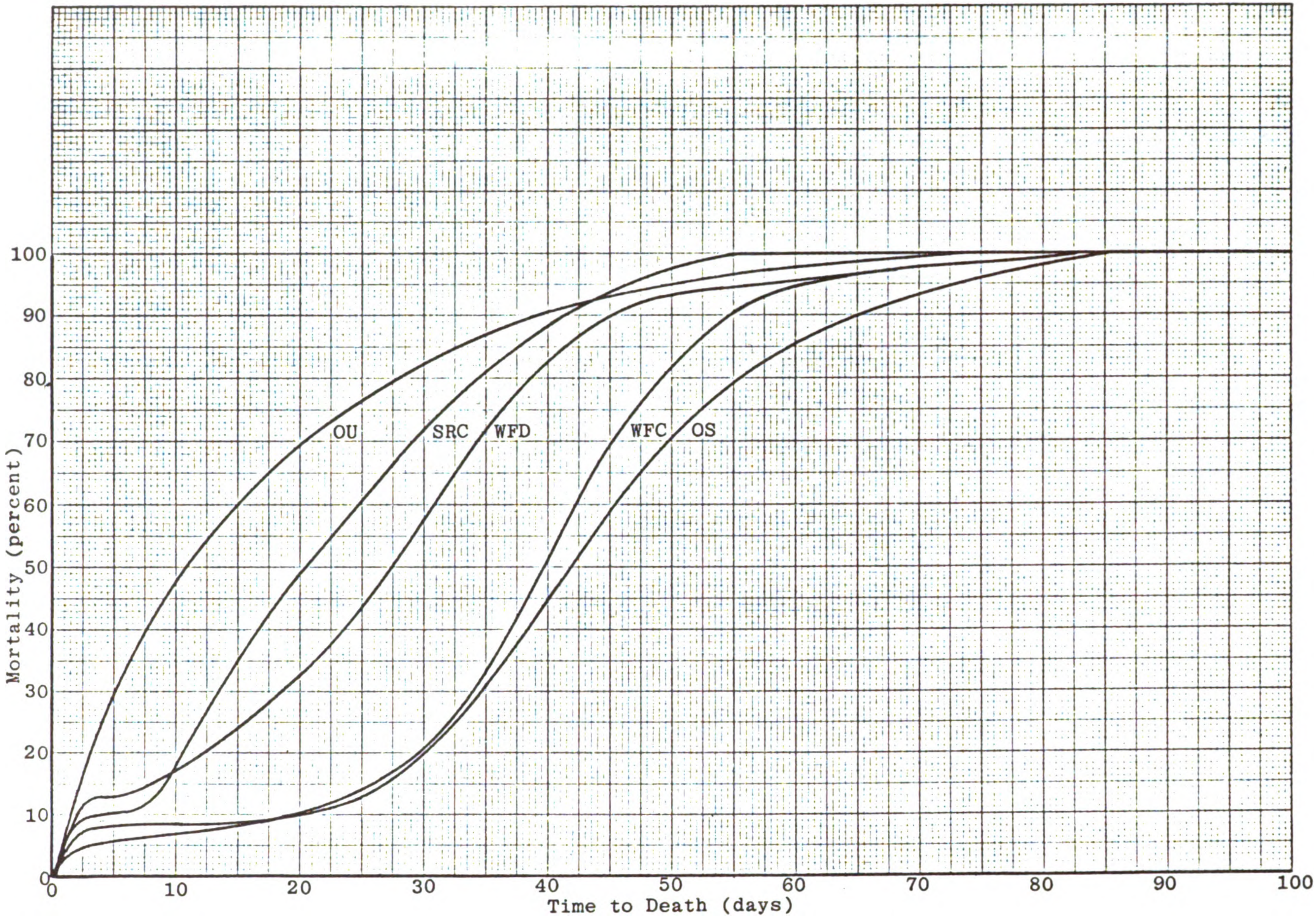

Figure 15. Mortally injured time-to-death curves for Hiroshima.

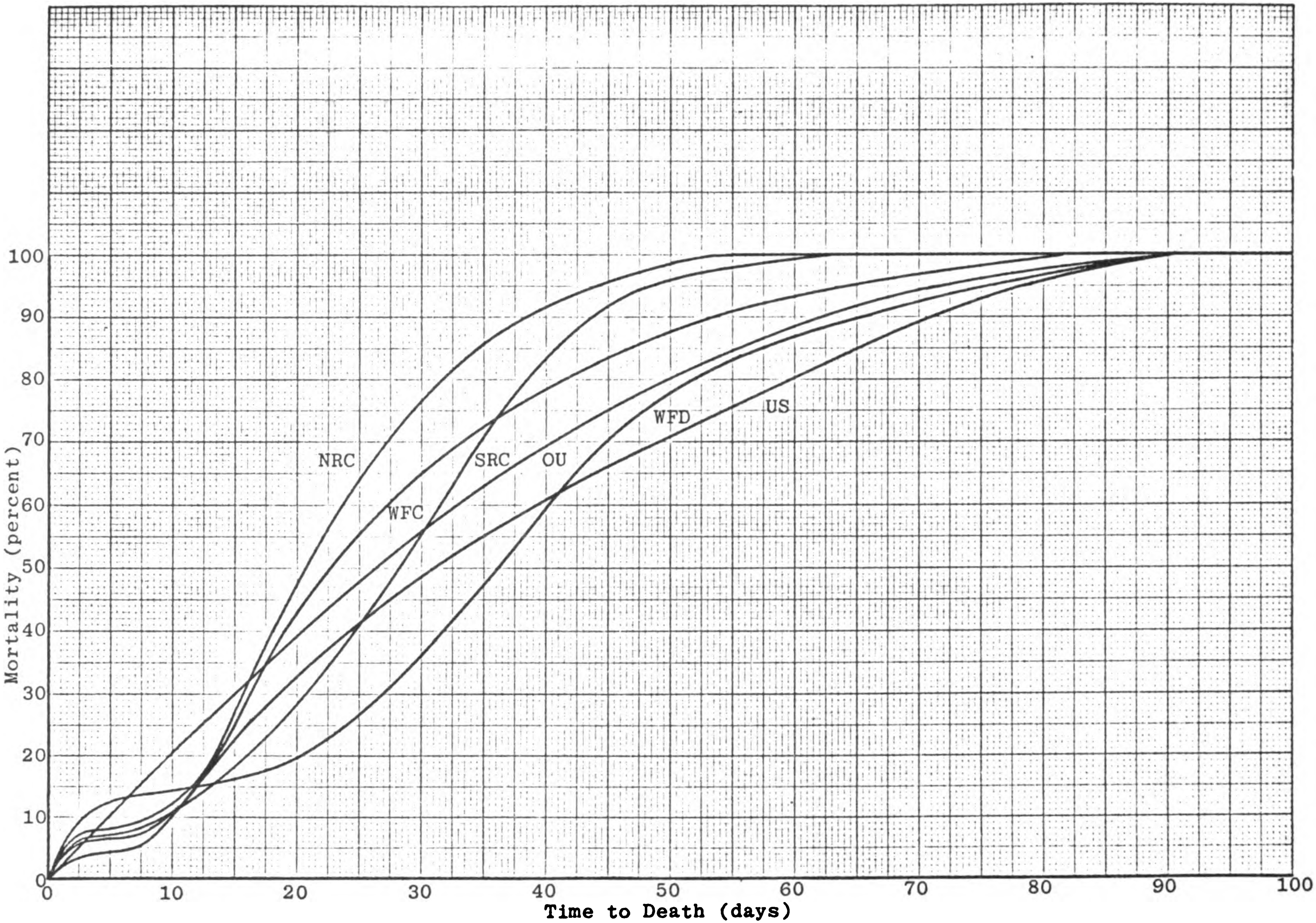

Figure 16. Mortally injured time-to-death curves for Nagaski.

injuries. The effect of initial-nuclear-radiation injuries on time to death is evidenced by the manner in which the curves for most of the shielding categories reach a plateau after a few days and do not again begin to increase rapidly until around 14 to 20 days. Any change in the mix of initial-nuclear radiation relative to the blast and prompt-thermal radiation would alter this plateau characteristic.

3-6 COMPOSITE TIME-TO-DEATH CURVES FOR JAPAN

In Reference 3, considerable effort was expended in examining the time-to-death data from Hiroshima and Nagasaki as well as from other sources. As a result of this analysis, a set of composite time-to-death curves by shielding category was developed which should be representative of both cities. These composite time-to-death curves are given in Figure 17, as replotted from Figure 9.1 of Reference 3. The principal reason for replotting both the time-to-death data from Reference 2 discussed above and that from Reference 3 was to present time in a compatible manner so that they could be more easily utilized and compared. The initial-nuclear-radiation injury plateau discussed previously makes direct scaling of these data to high yields impossible, but they could probably be used for low kiloton yields if the nuclear radiation mix is not drastically different. The development of time-to-death curves compatible with high-yield nuclear weapons and the required scaling procedures are given in Reference 3.

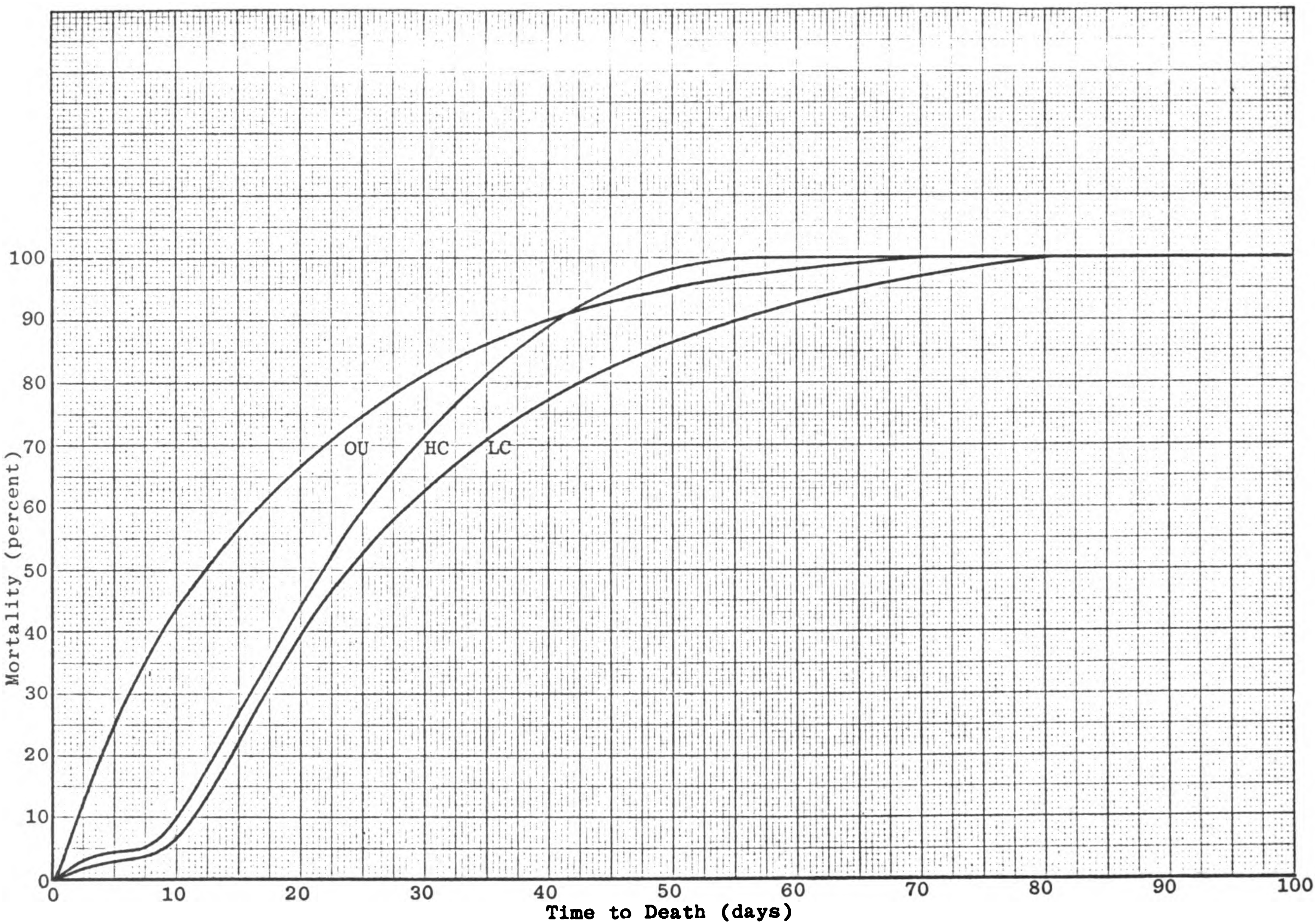

Figure 17. Composite mortally injured time-to-death curves for Japan.

CHAPTER 4
INJURY

4-1 INTERDEPENDENCE OF TOTAL MORTALITY AND INJURY DATA

In the context of the analysis performed in References 2 and 3, persons classified as injured (not mortally injured) were defined as injured survivors. Thus, for any shielding category all persons who died within 90 days after the burst were included in the associated total mortality curve. In the higher mortality regions (above 50 percent), the shape of the total injury curve is essentially determined by subtracting the mortality percentage from 100 since nearly everyone is either killed or injured. The curves for the mortally injured (difference between total mortality and killed-immediately) were discussed previously in Sections 3-5 and 3-6 of Chapter 3.

4-2 TOTAL INJURY

The injury data presented here were obtained from Reference 2 if they were not revised by data from Appendix A of Reference 3. The injury curves for each shielding category consist of the total injury curve, blast injury curve, prompt-thermal injury curve, and initial-nuclear-radiation injury curve. Dashed lines indicate areas where data were especially sparse, so these curves are probably less reliable. Additional detail concerning the applicable data bases and the important features of the injury curves are given in Reference 2, while Reference 3 gives detail regarding revision criteria used in developing the revised curves presented here. Specifically, the shielding categories of light steel-frame buildings (LSF), wood-frame commercial buildings (WFC), wood-frame dwellings (WFD), outside-shielded by buildings (OS), and outside-unshielded (OU) were all obtained from Reference 3 in both Hiroshima and Nagasaki; the category for vehicles (V) came from the same reference source for Hiroshima only. All other shielding categories for both cities came from Reference 2.

The injury data from these two sources form a current, complete set by shielding category for both cities that are compatible with the associated total mortality curves by shielding category discussed in Chapter 3. The injury curves for Hiroshima are given in Figures 18 through 27 and the curves for Nagasaki are presented in Figures 28 through 37.

4-3 ADDITIONAL PROMPT-THERMAL INJURY

Figure 38 presents the predicted prompt-thermal (flash-burns) injury curve for persons in Japan exposed to direct prompt-thermal radiation (outside-unshielded) as a function of exposure level (cal/cm^2) for a 12.5 KT surface burst (see Figure 3.26 in Reference 3). With the data in this form, they are readily scaled to other yields of interest.

As an added insight into prompt-thermal injuries, flash burns by degree versus horizontal range are presented in Figures 39 (Hiroshima) and 40 (Nagasaki). These curves are for persons exposed to direct prompt-thermal radiation (outside unshielded) and provide additional data concerning the severity of flash burns by horizontal range in the two cities. A dashed line indicates where only sparse data were available. For additional detail consult Reference 2.

4-4 COMBINATION OF INJURY

As explained in Chapter V of Reference 3, the data were too sparse in Nagasaki to define meaningful curves so only data from Hiroshima are presented here. In the previous analysis only five injury combinations (some occurring singly) were found to be dominant for persons inside or shielded by structures. (All other combinations were of minor significance.) These five dominant, mutually exclusive, injury combinations for persons in or shielded by strctures were as follows: moderate blast injuries only, severe blast injuries only, moderate initial-nuclear and moderate blast injuries, severe initial-nuclear and moderate blast injuries, and moderate prompt-thermal injuries only. Also, five different

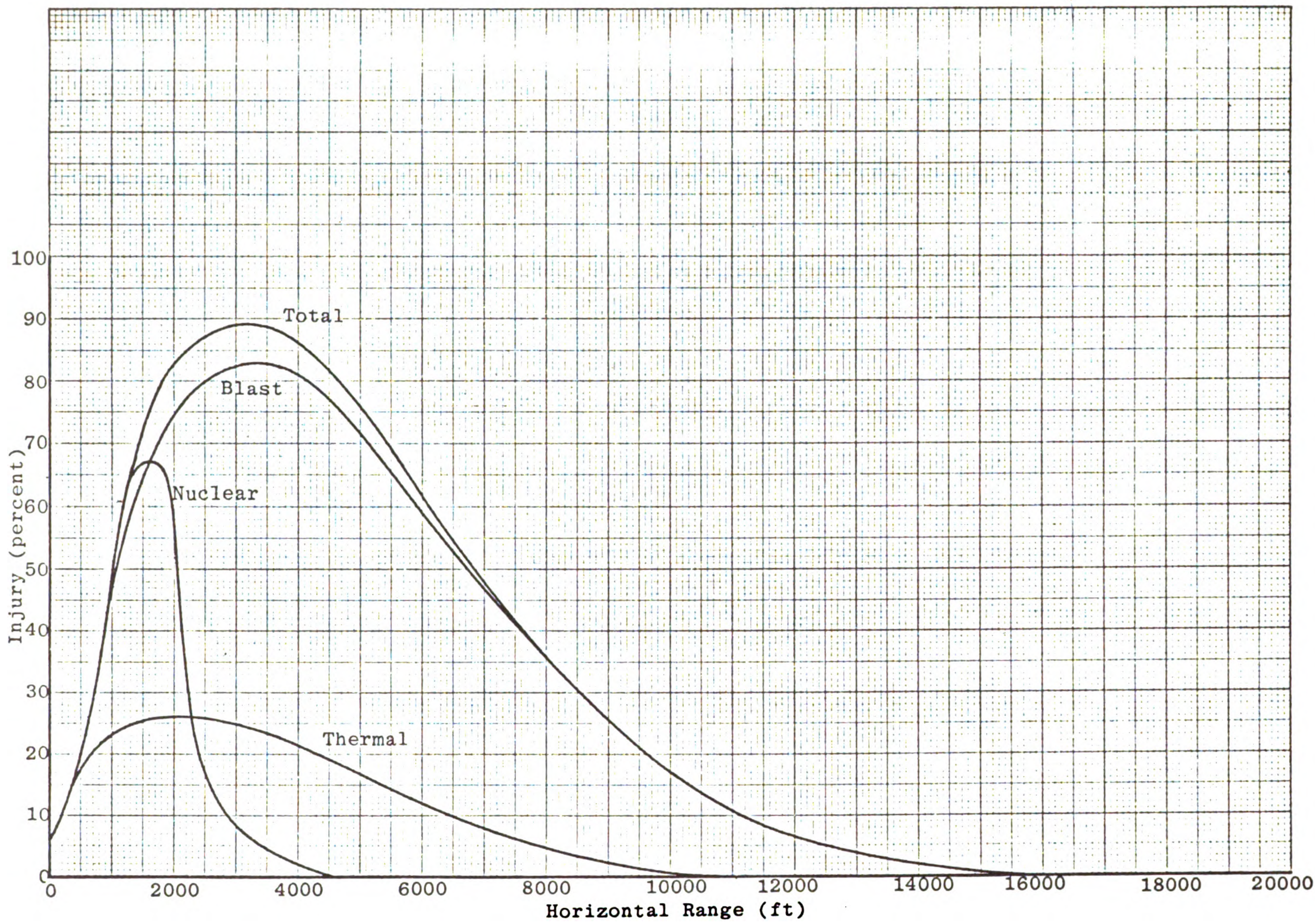

Figure 18. Hiroshima injury curves for seismic reinforced-concrete buildings.

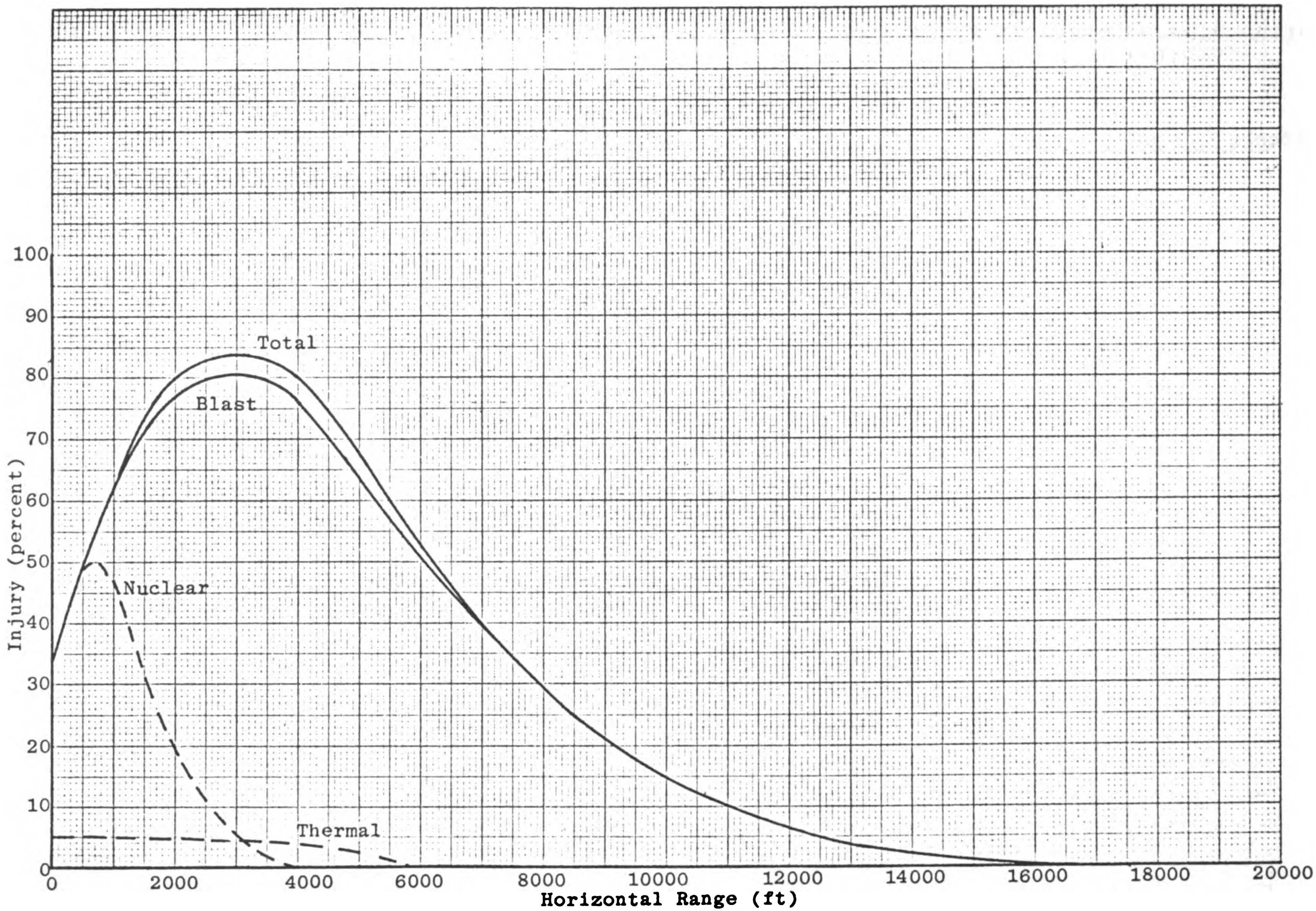

Figure 19. Hiroshima injury curves for basements of seismic reinforced-concrete buildings.

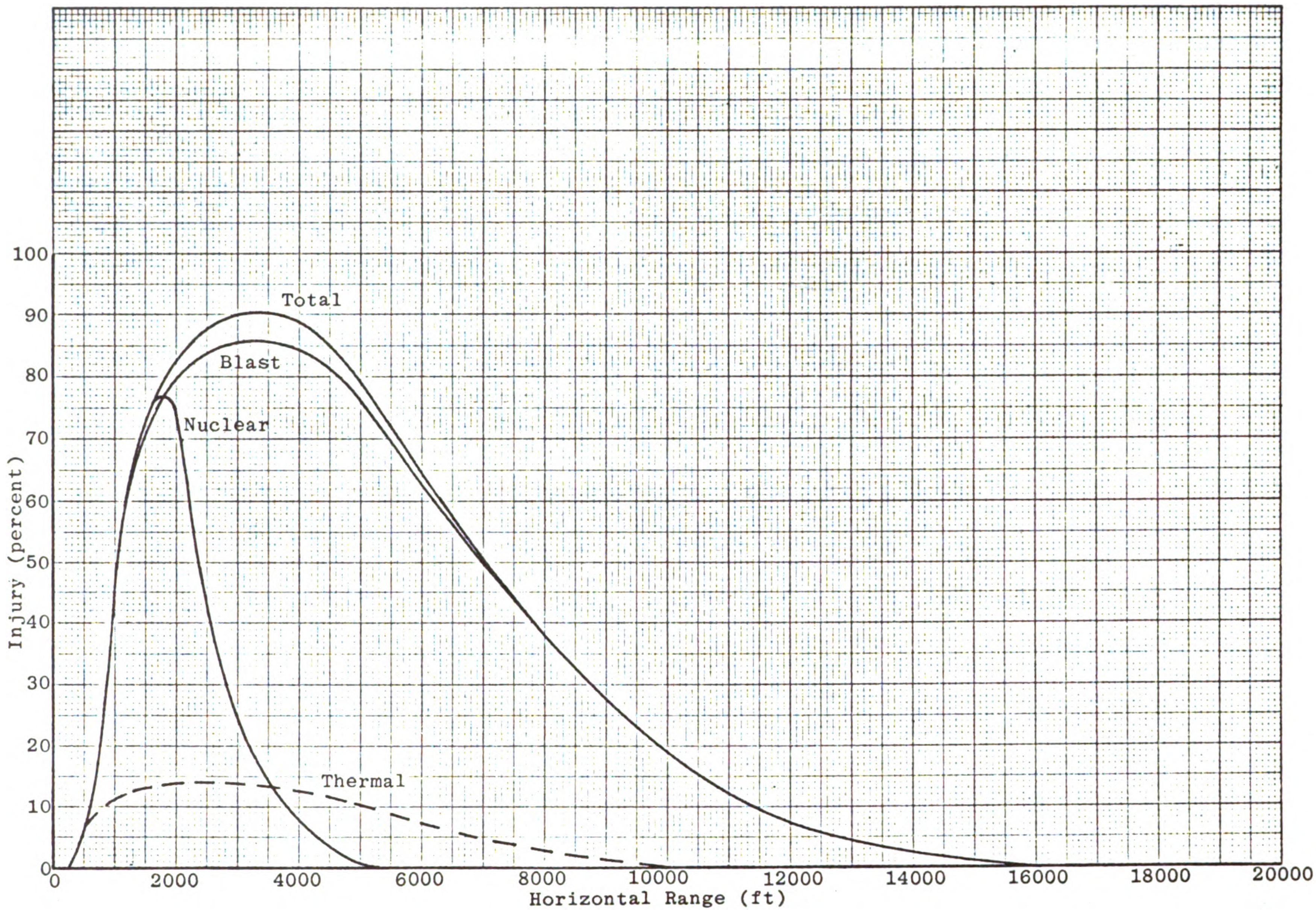

Figure 20. Hiroshima injury curves for middle floors of seismic reinforced-concrete buildings.

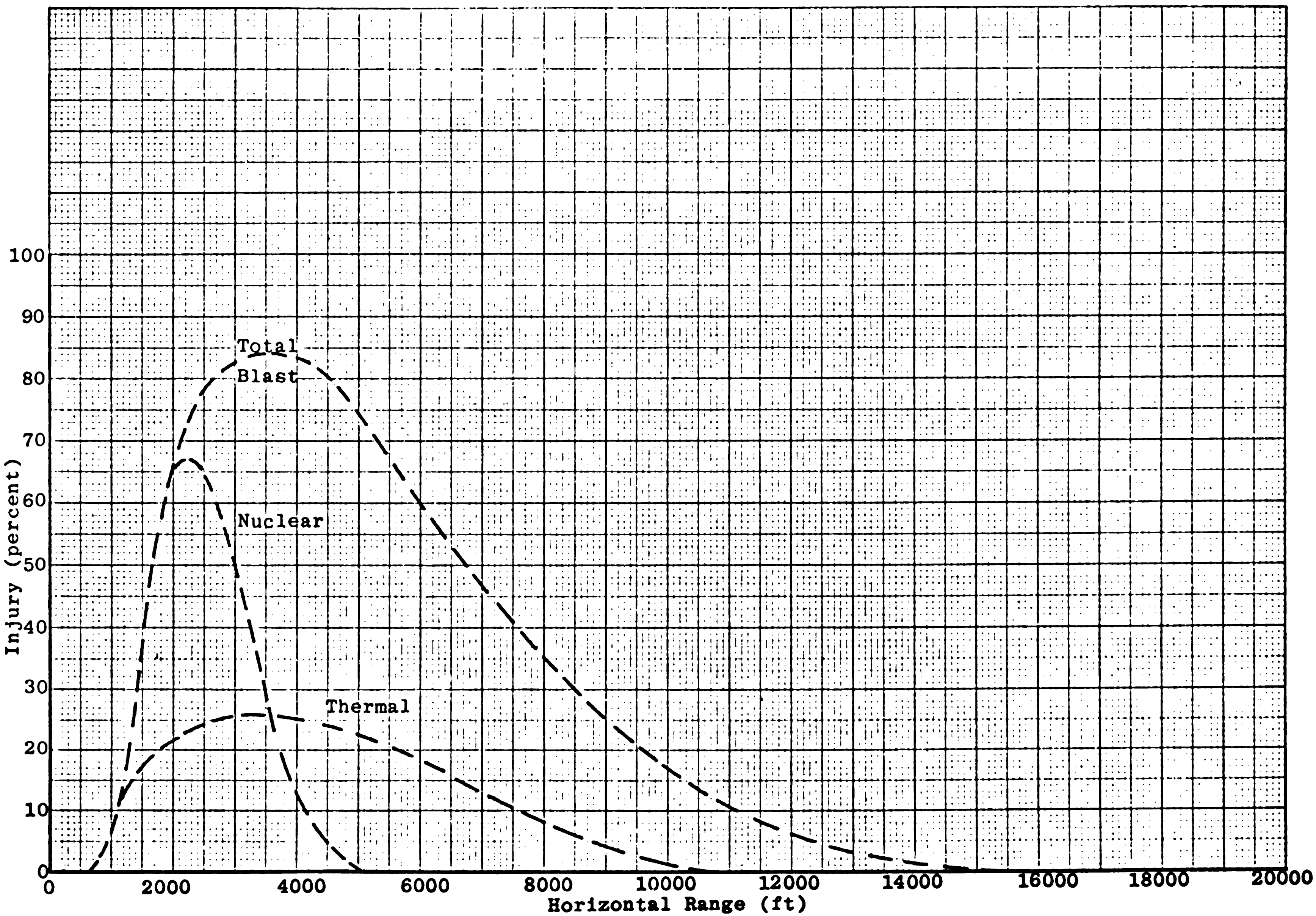

Figure 21. Hiroshima injury curves for nonseismic reinforced-concrete buildings.

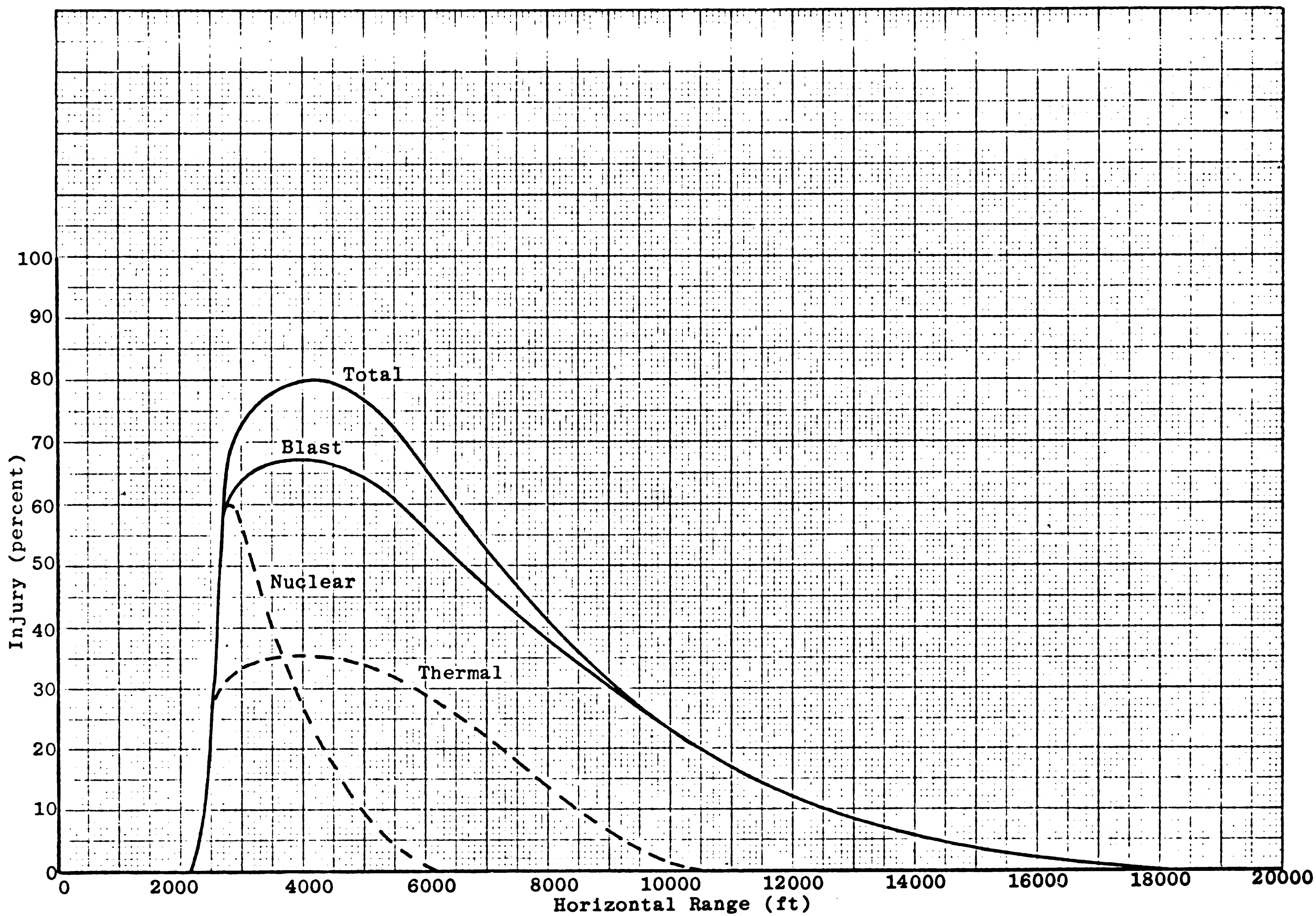

Figure 22. Hiroshima injury curves for light steel-frame industrial buildings.

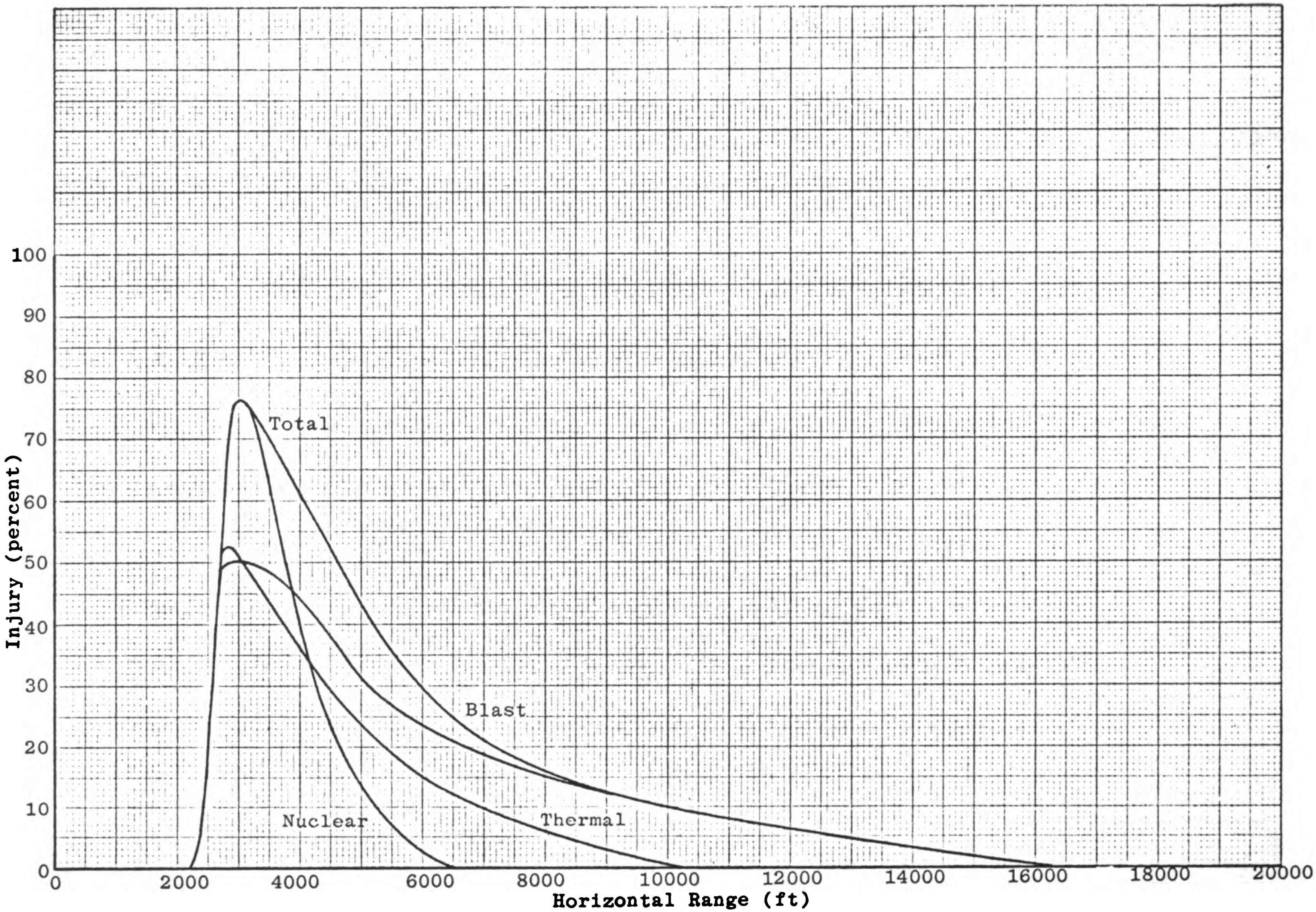

Figure 23. Hiroshima injury curves for vehicles.

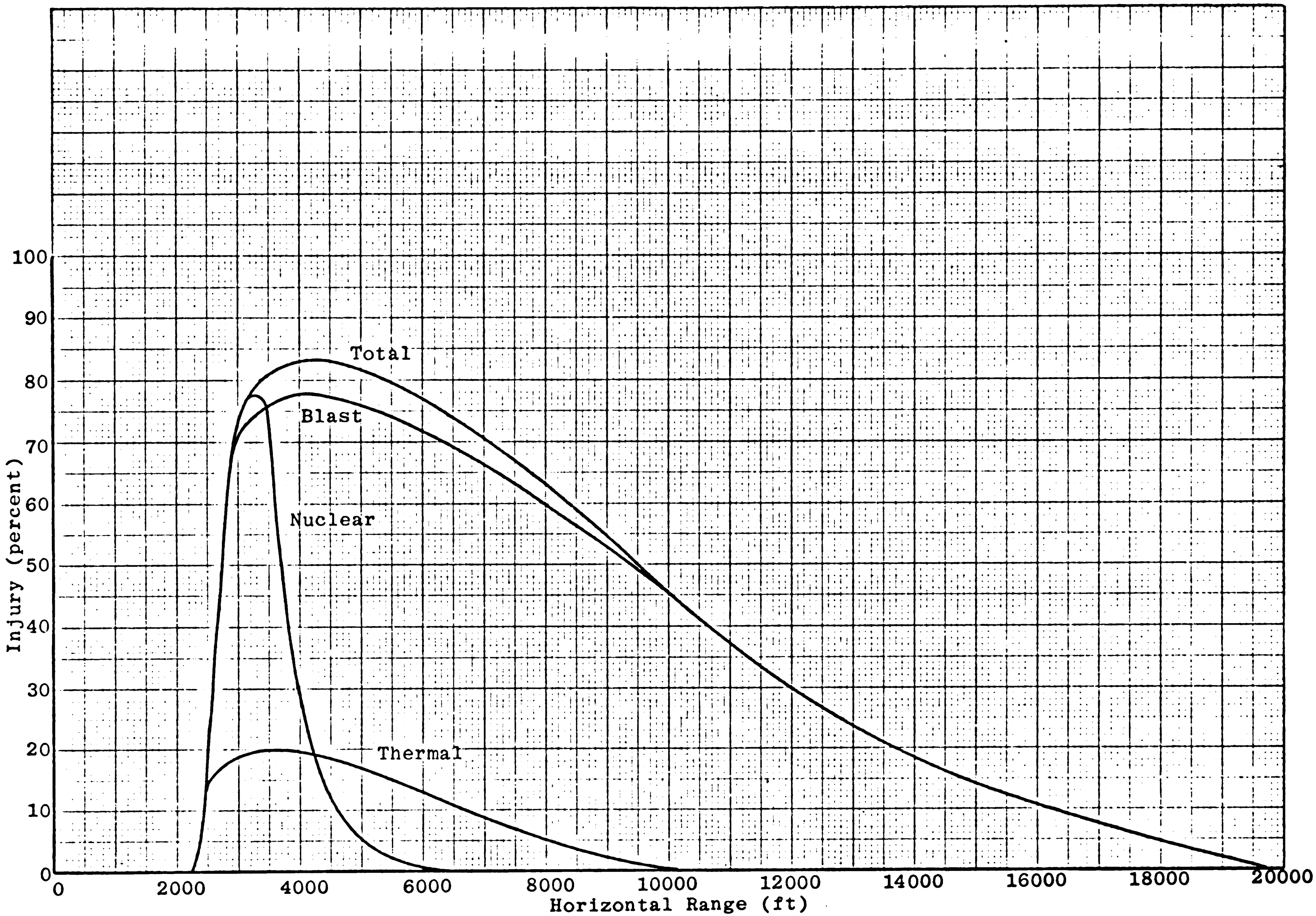

Figure 24. Hiroshima injury curves for wood-frame commercial buildings.

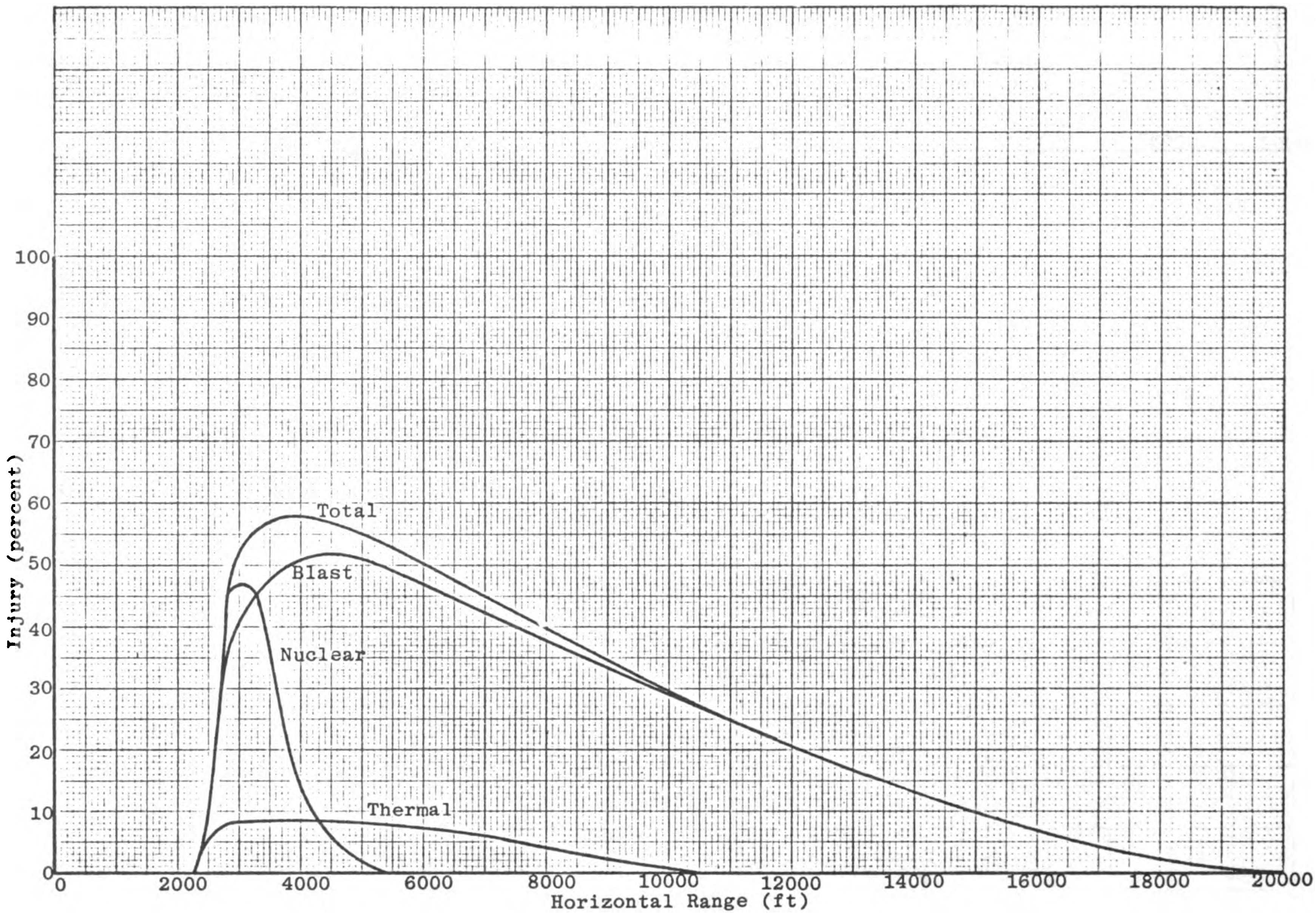

Figure 25. Hiroshima injury curves for wood-frame dwellings.

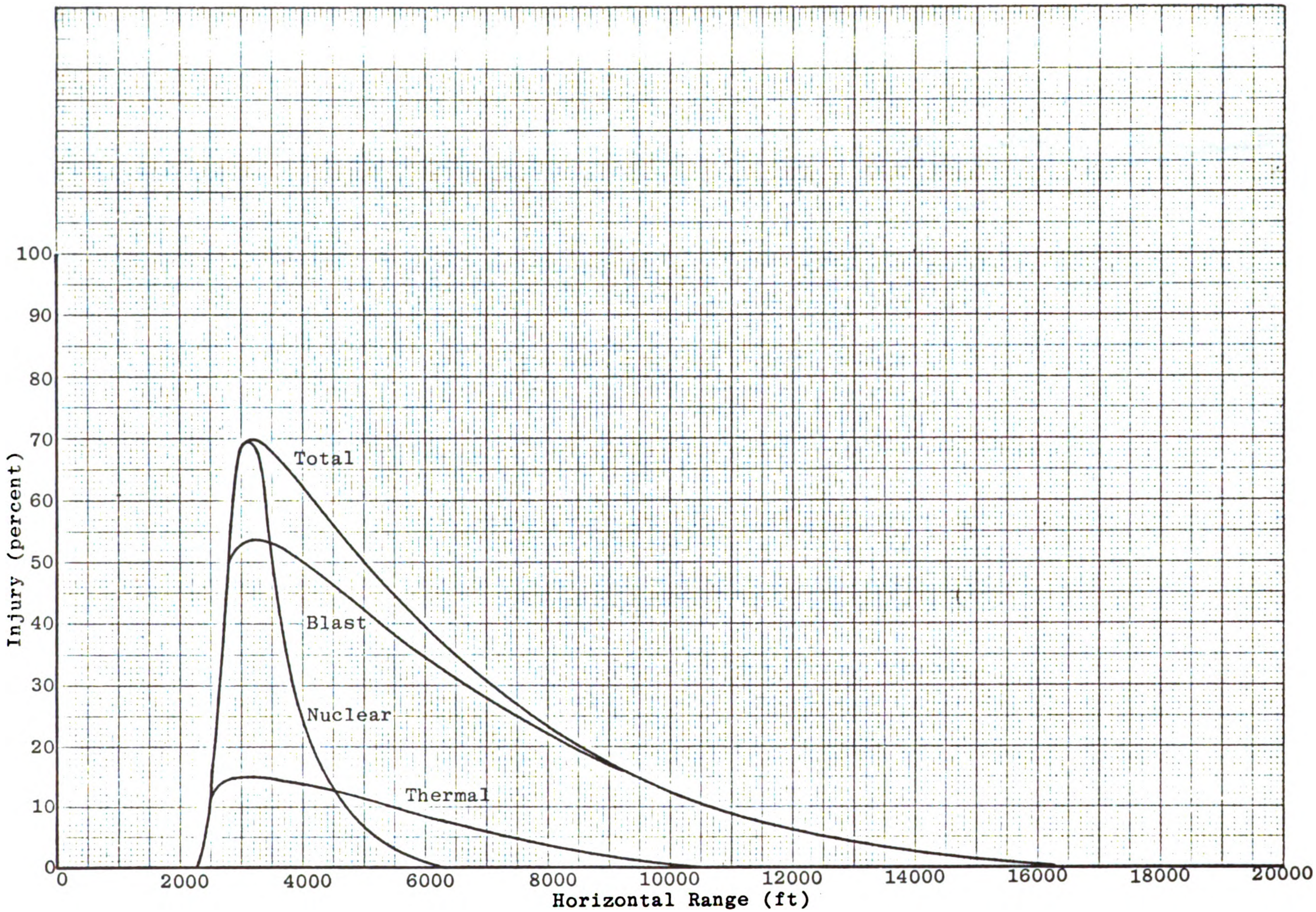

Figure 26. Hiroshima injury curves for outside-shielded persons.

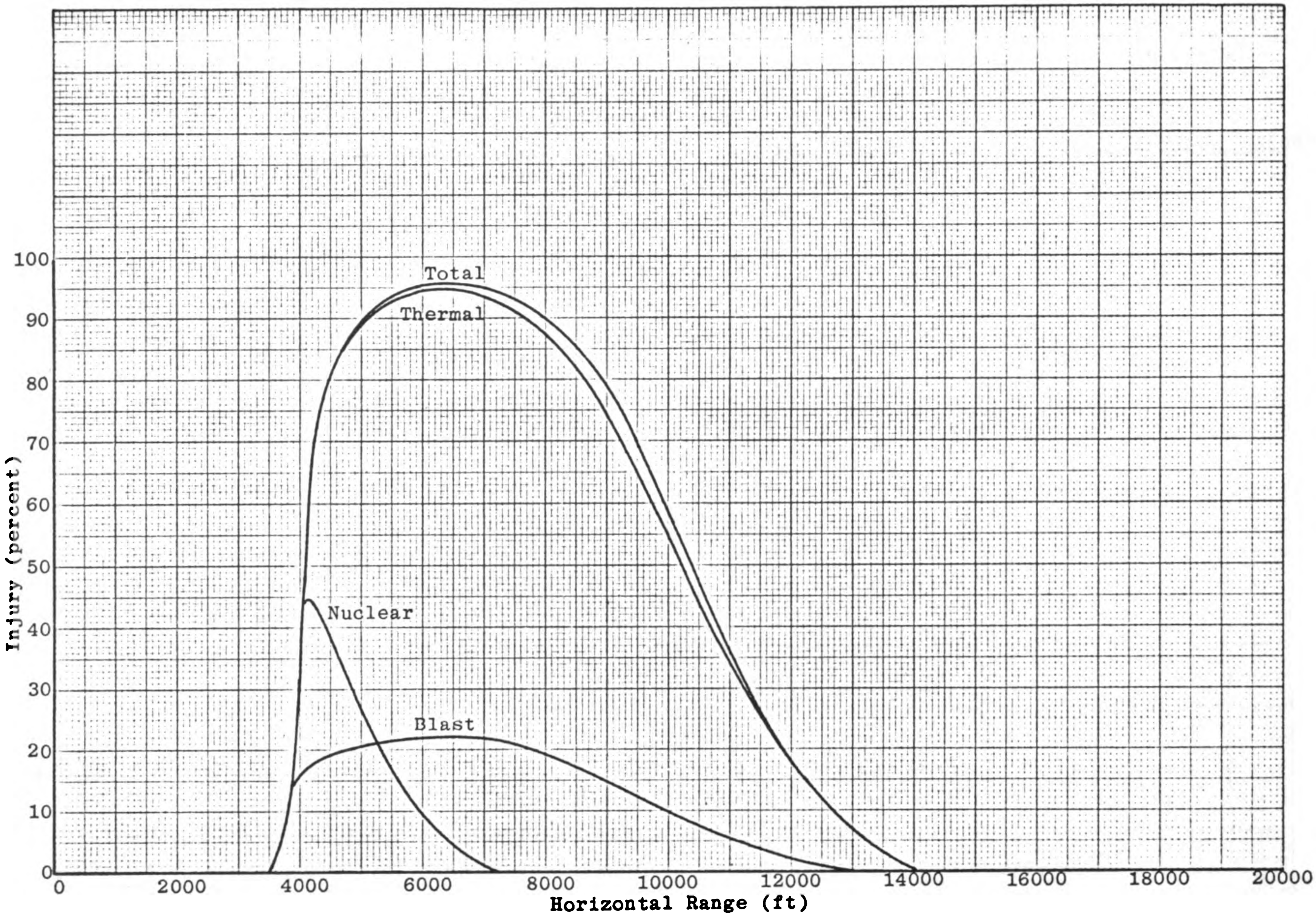

Figure 27. Hiroshima injury curves for outside-unshielded persons.

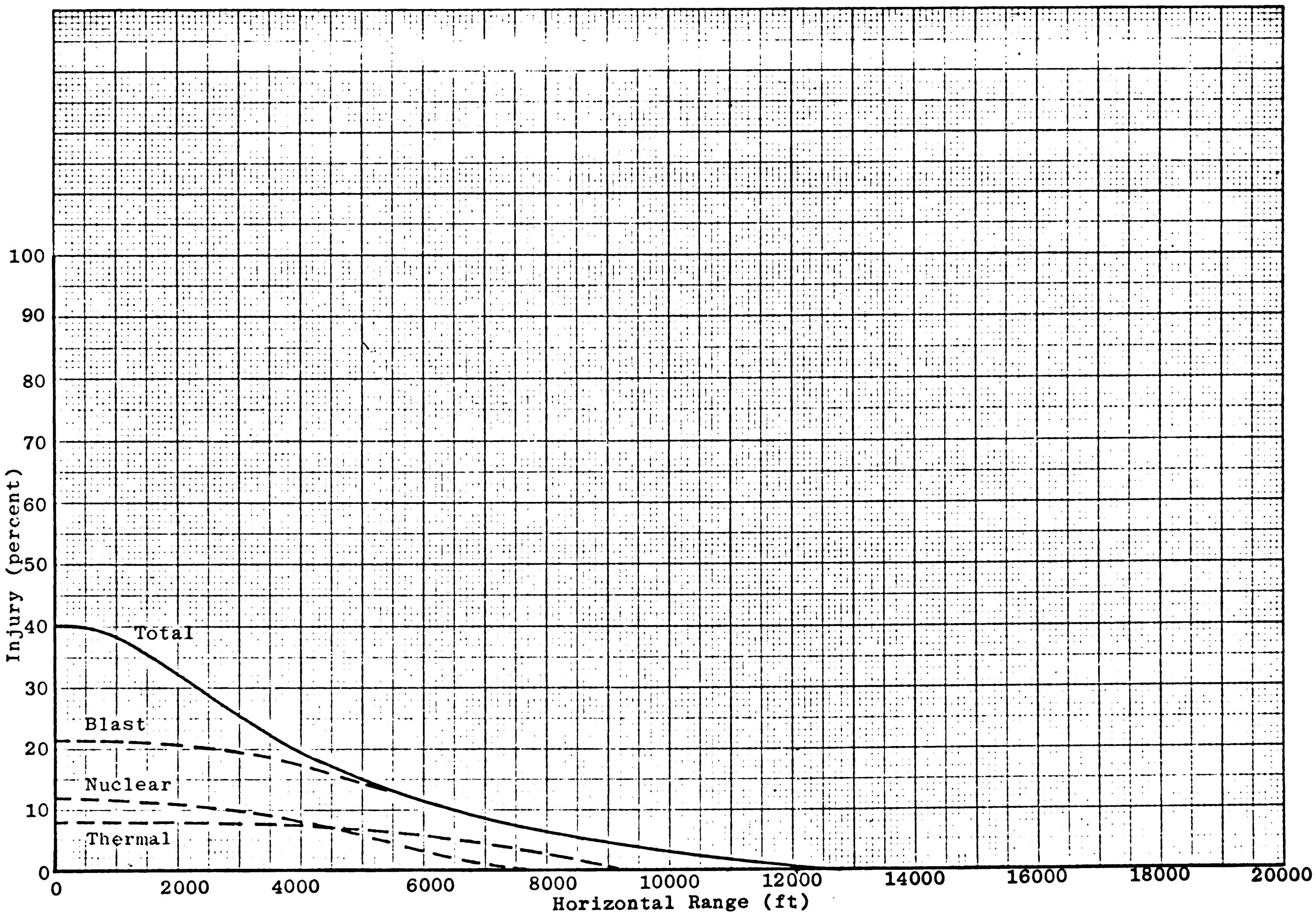

Figure 28. Nagasaki injury curves for miscellaneous underground shelters.

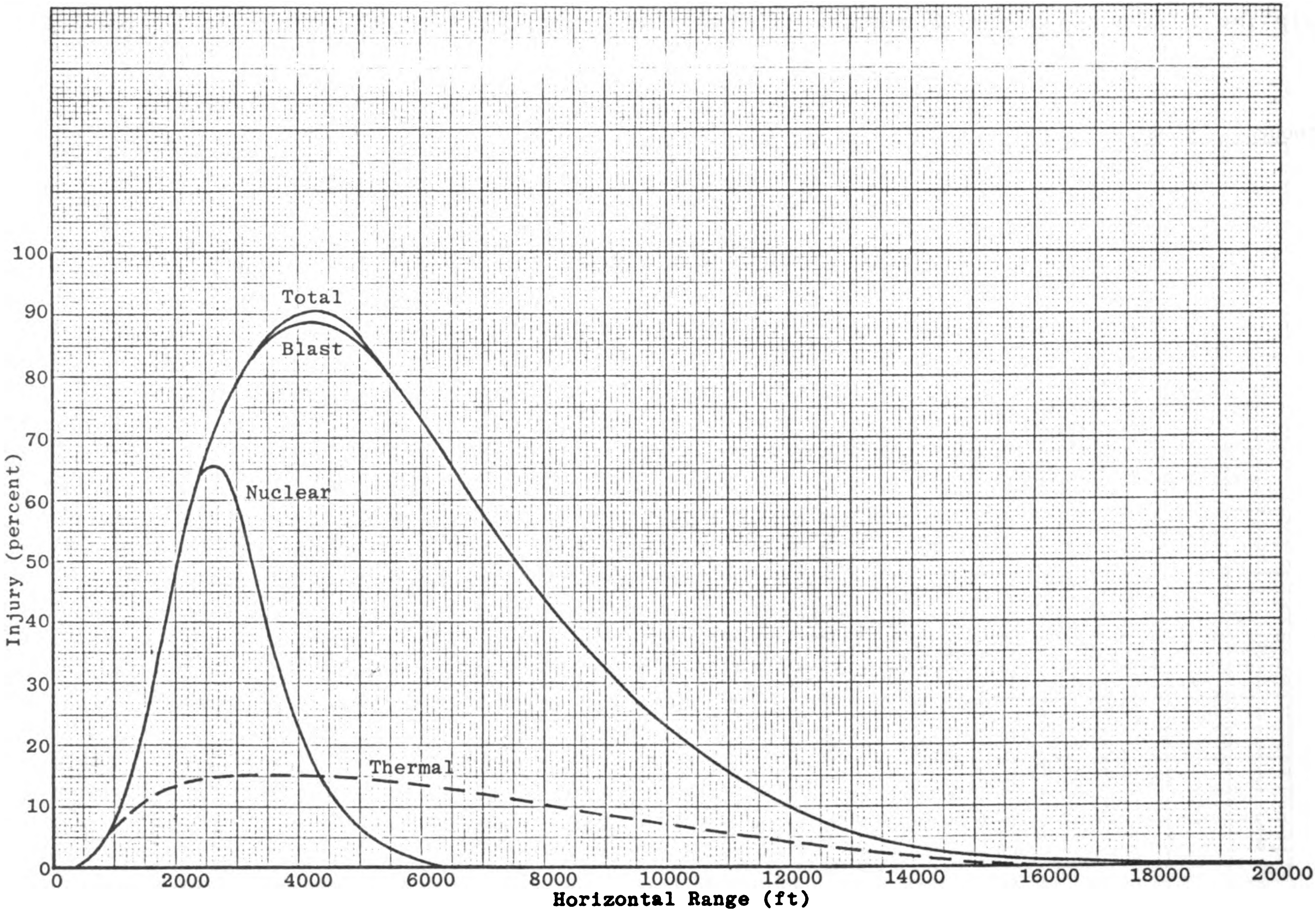

Figure 29. Nagasaki injury curves for seismic reinforced-concrete buildings.

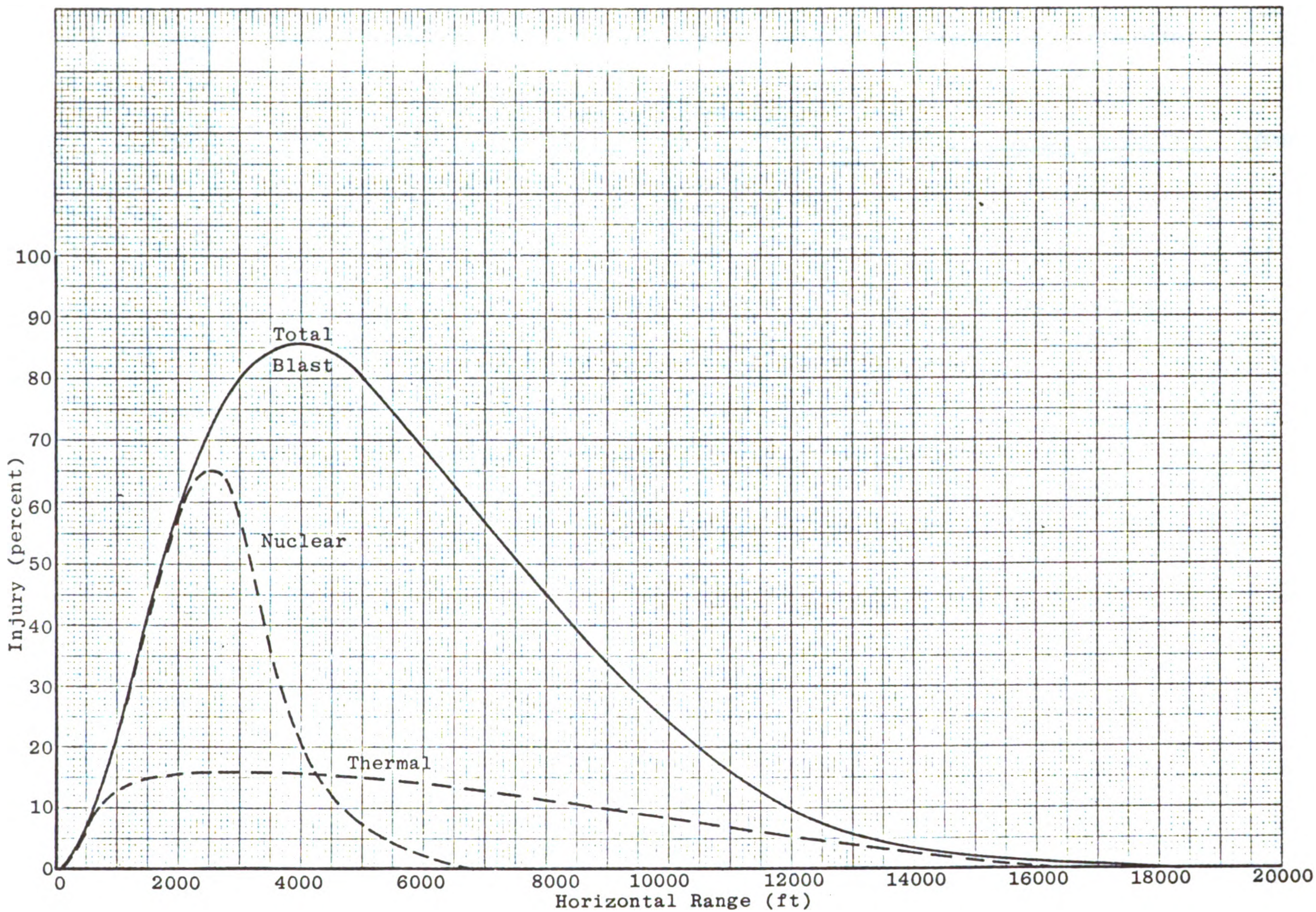

Figure 30. Nagasaki injury curves for lower floors of seismic reinforced-concrete buildings.

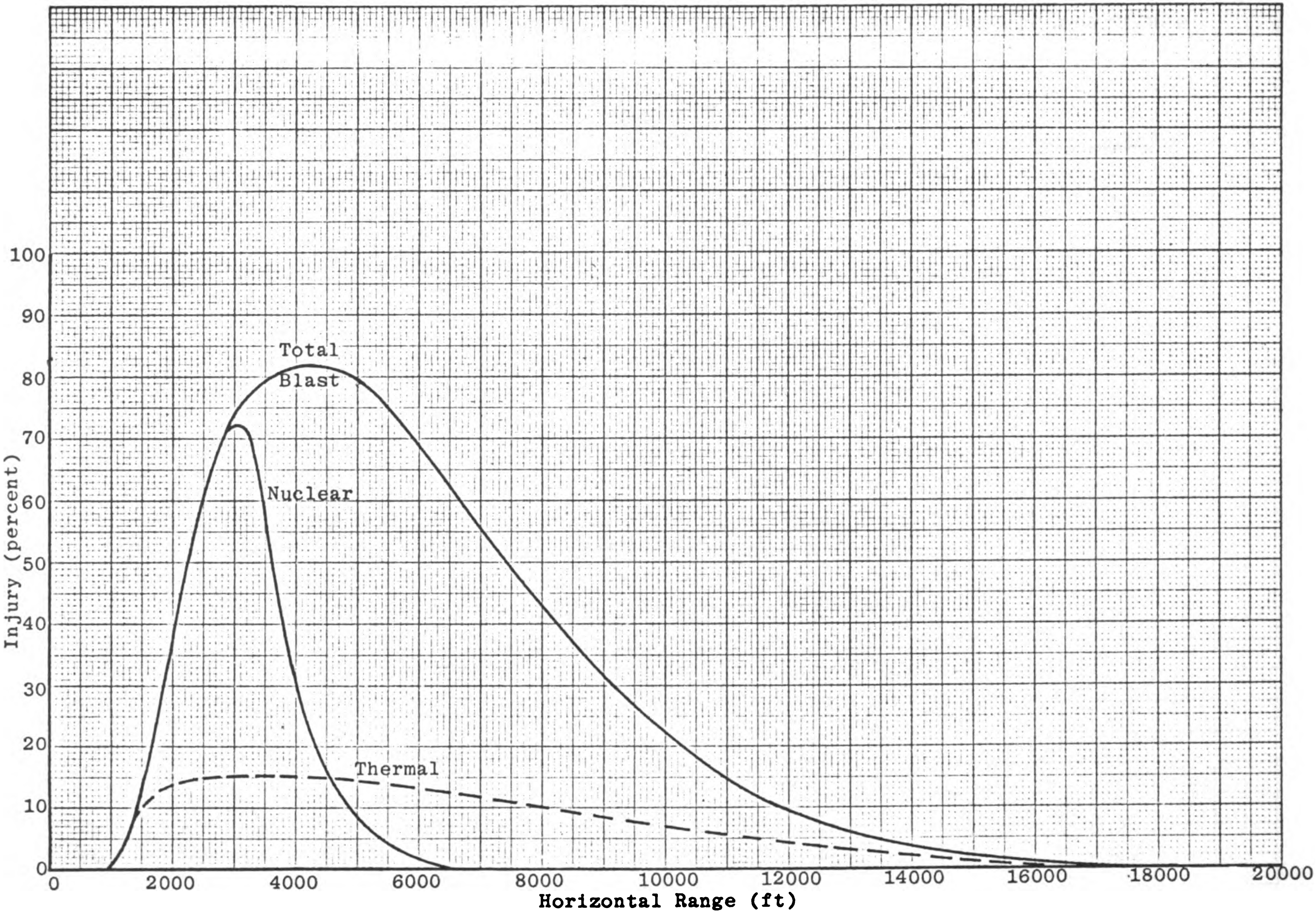

Figure 31. Nagasaki injury curves for middle floors of seismic reinforced-concrete buildings.

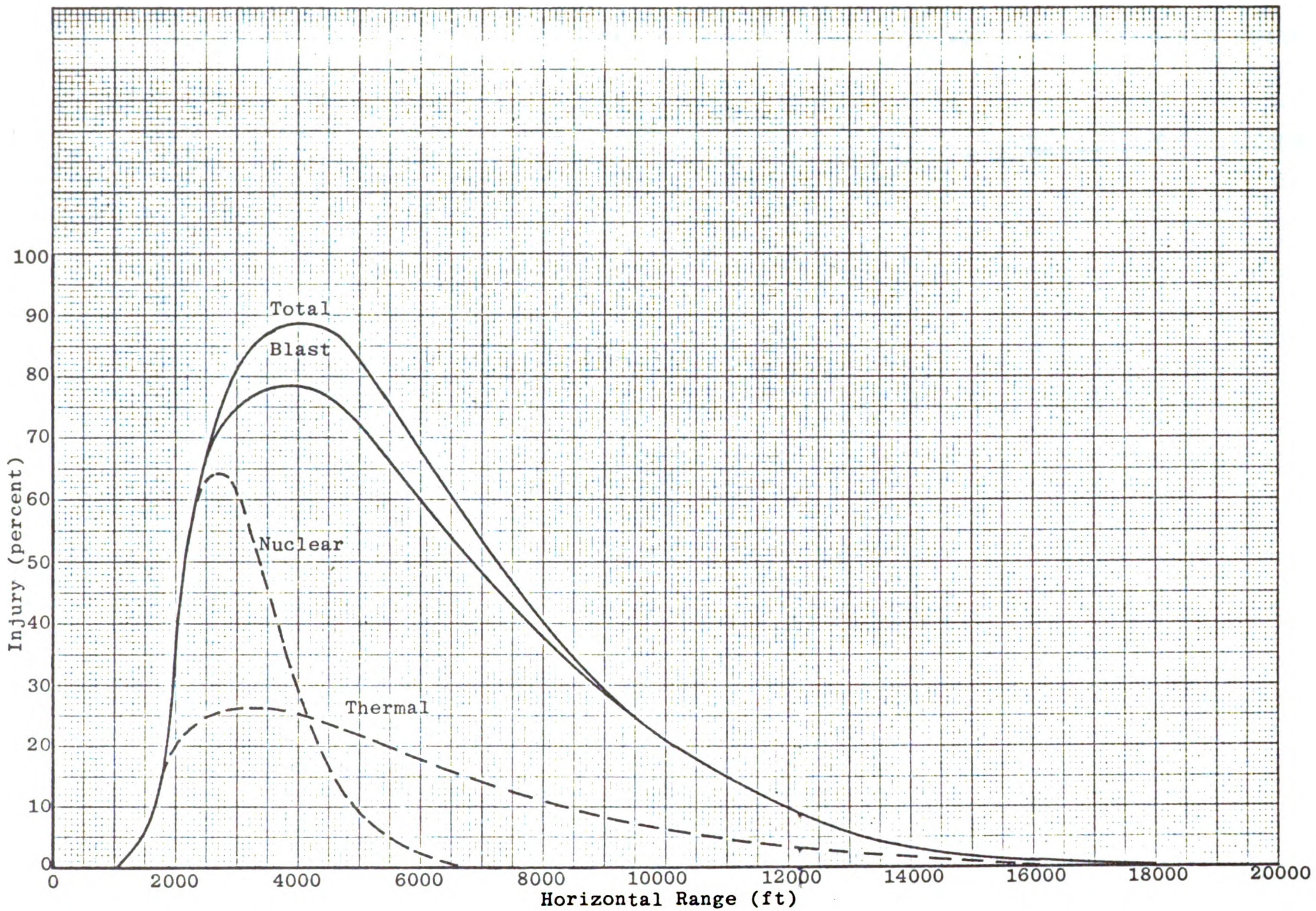

Figure 32. Nagasaki injury curves for nonseismic reinforced-concrete buildings.

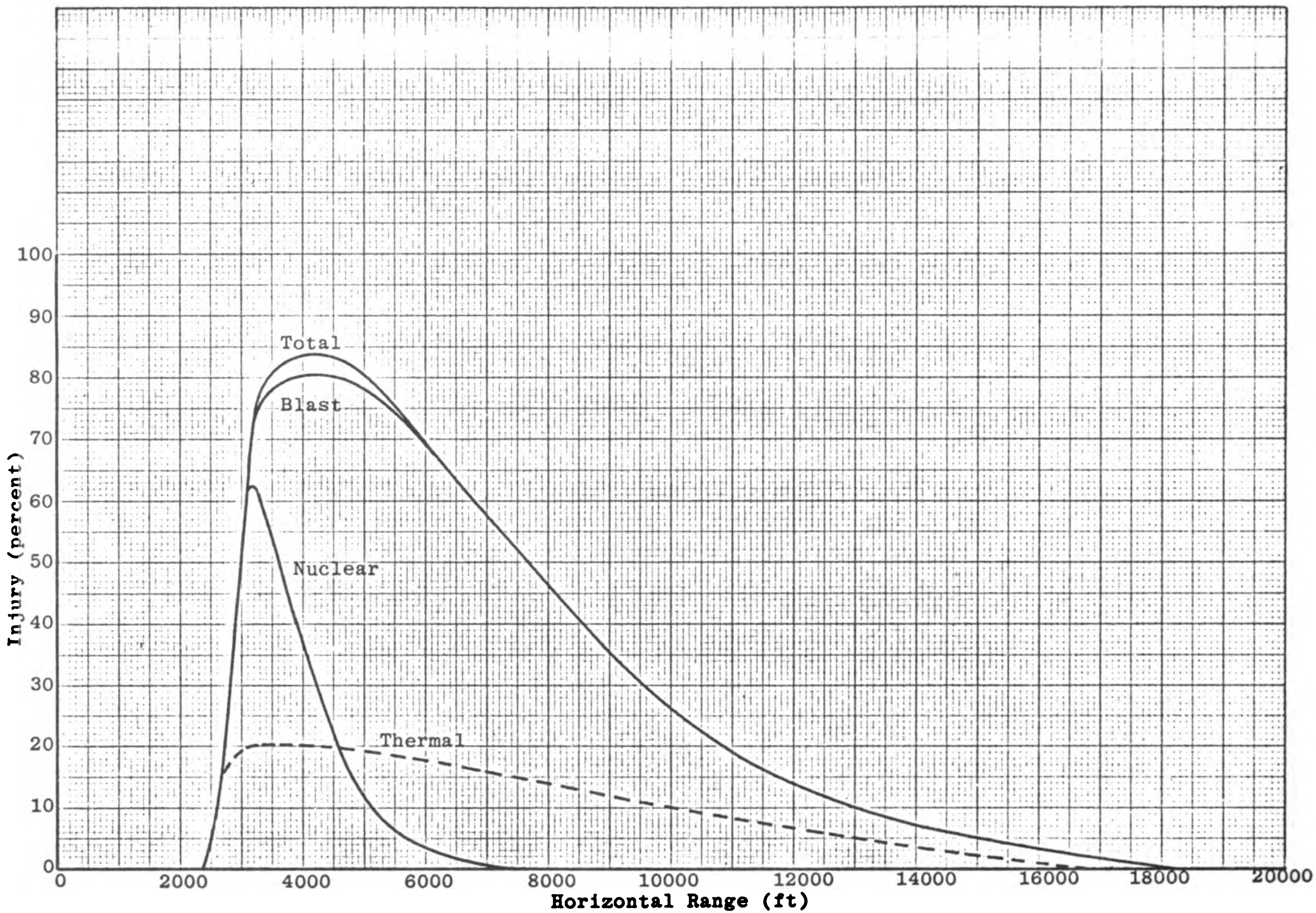

Figure 33. Nagasaki injury curves for light steel-frame industrial buildings.

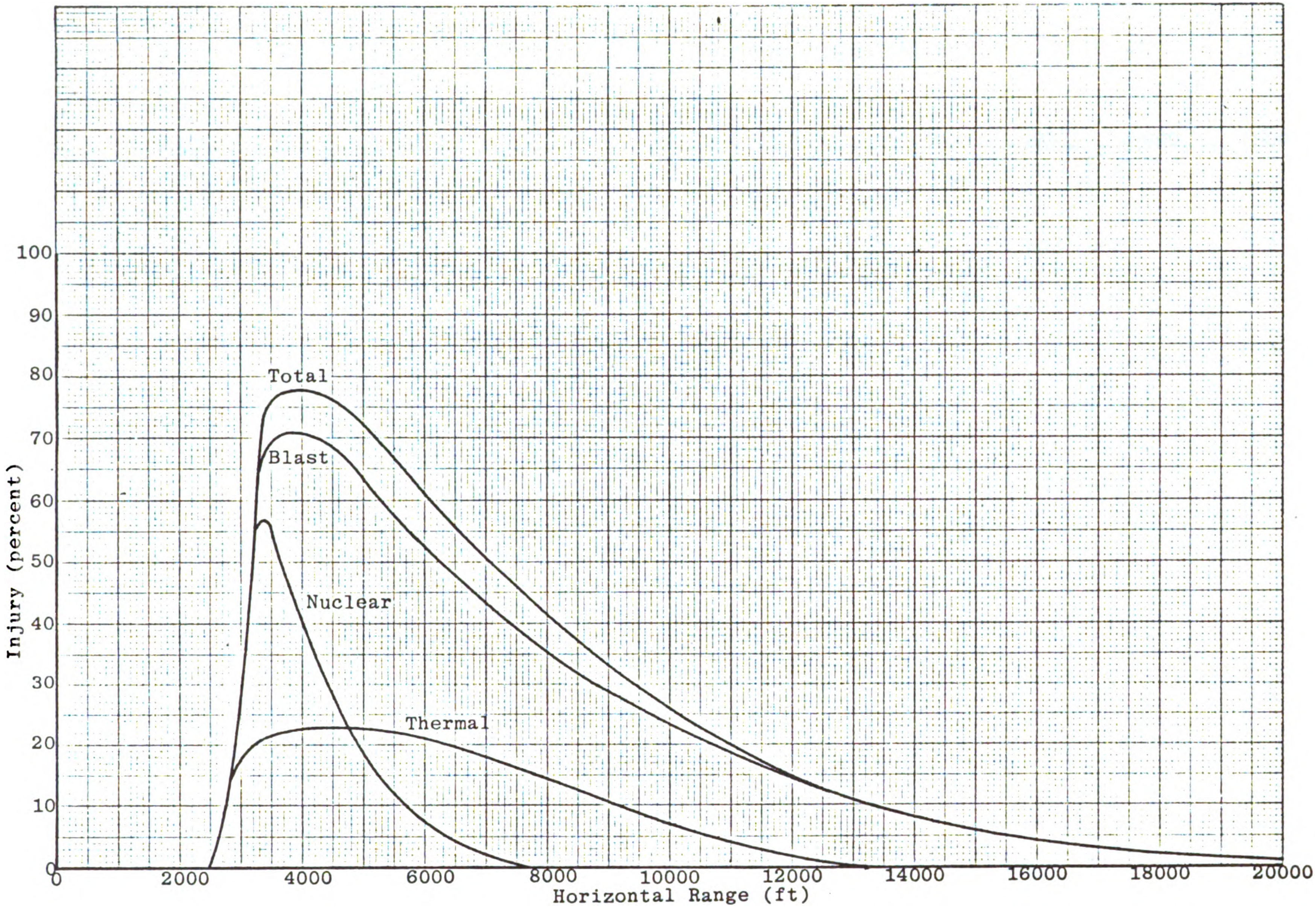

Figure 34. Nagasaki injury curves for wood-frame commercial buildings.

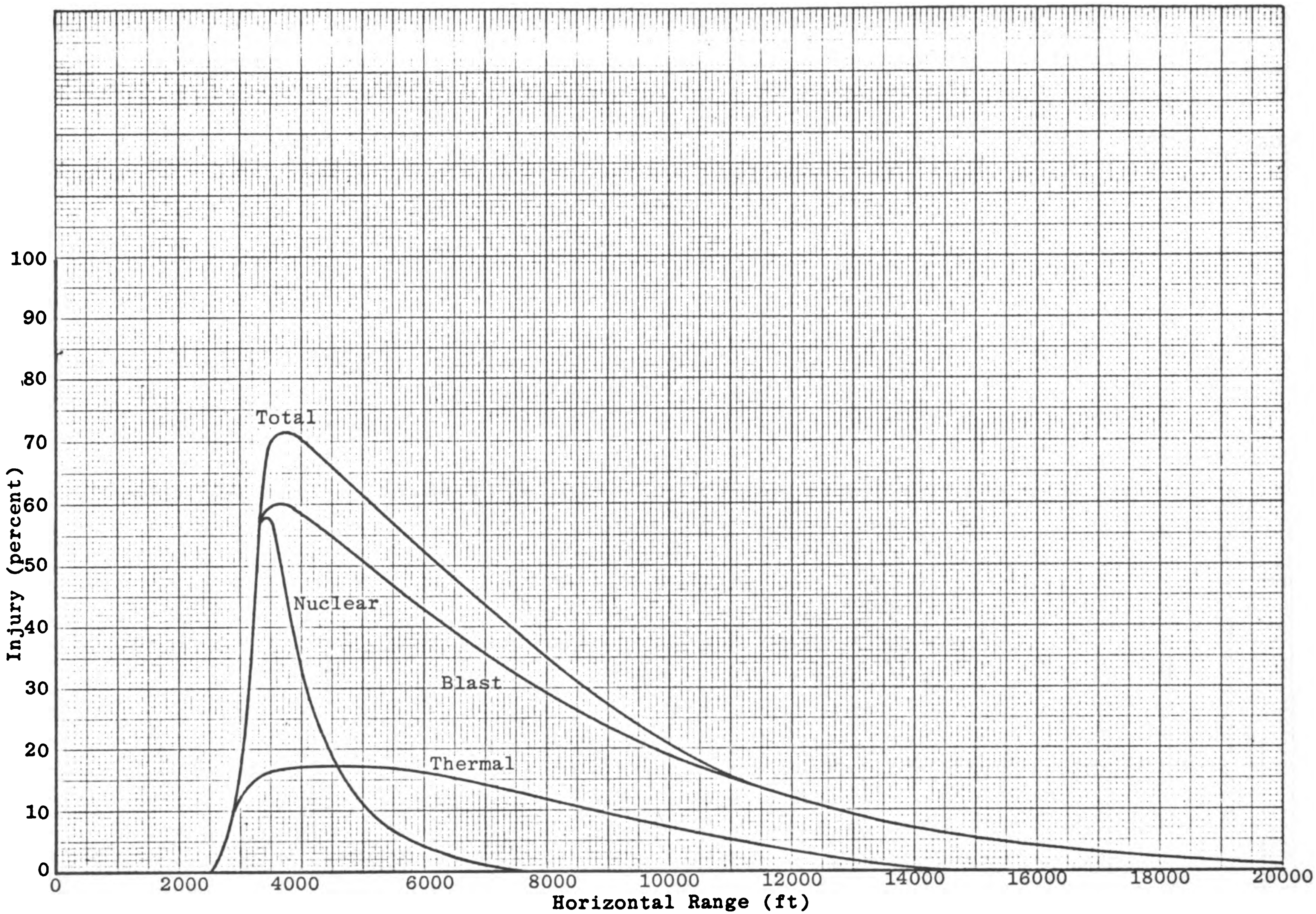

Figure 35. Nagasaki injury curves for wood-frame dwellings.

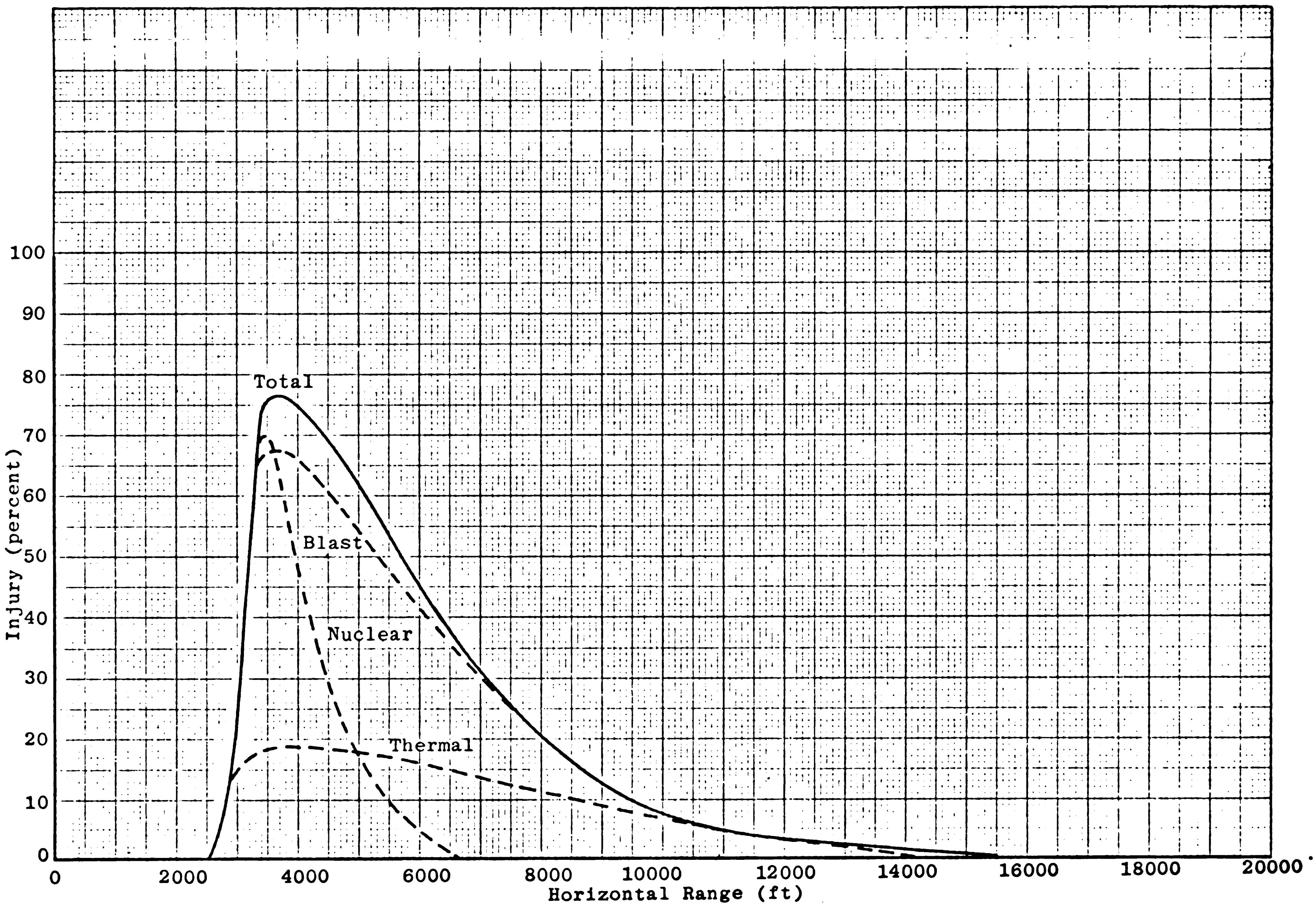

Figure 36. Nagasaki injury curves for outside-shielded persons.

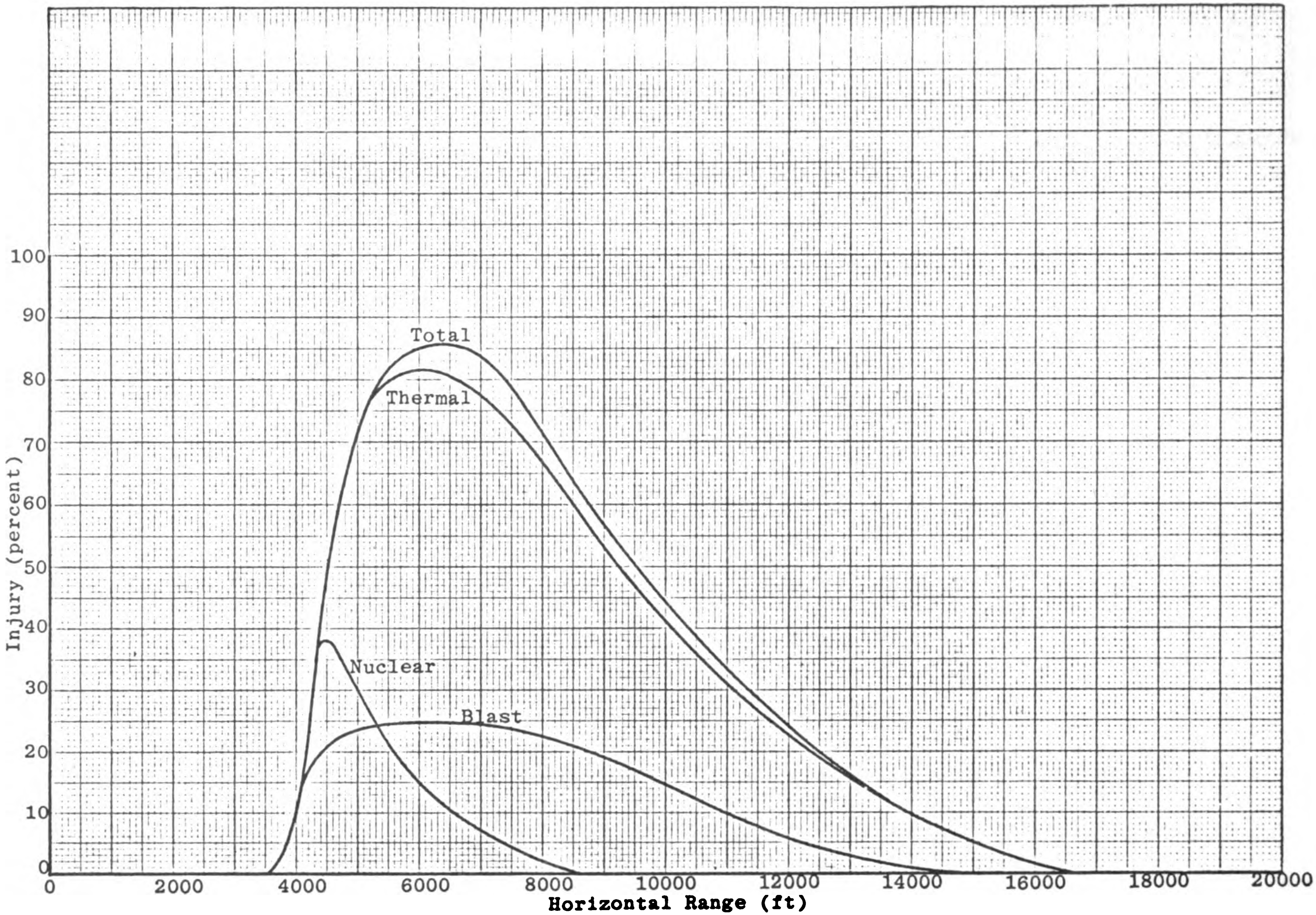

Figure 37. Nagasaki injury curves for outside-unshielded persons.

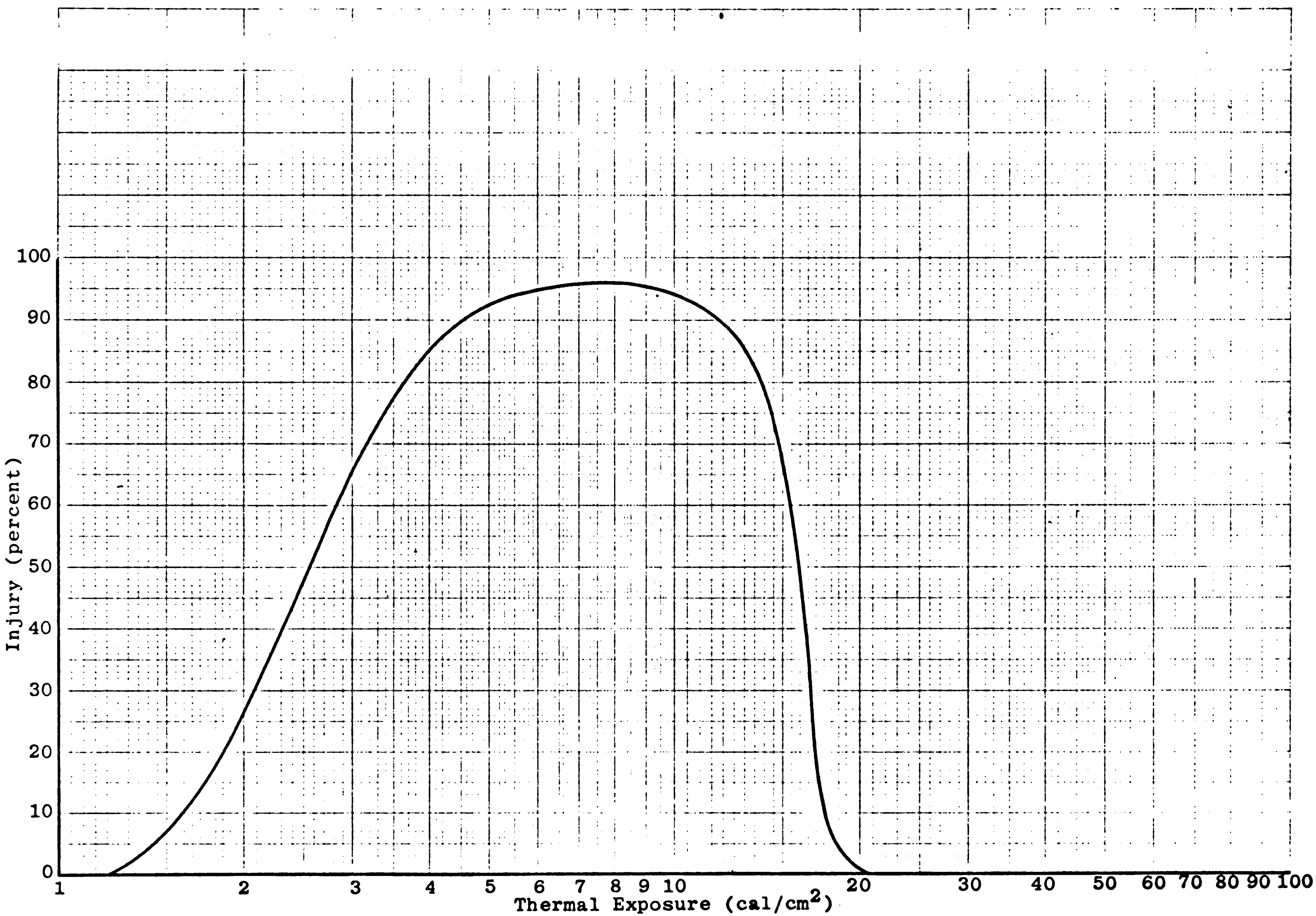

Figure 38. Prompt-thermal injury for outside-unshielded persons (12.5 KT surface burst).

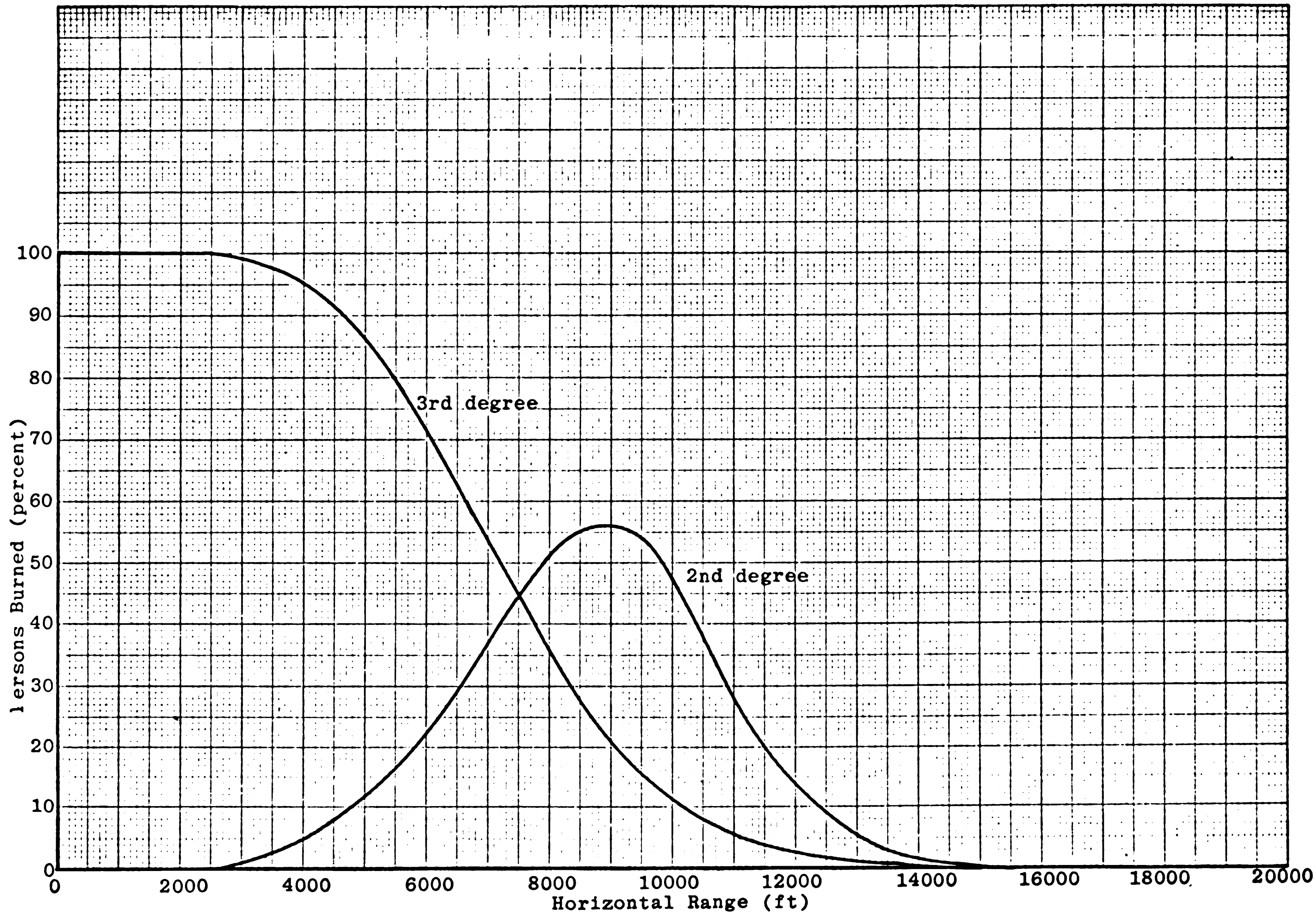

Figure 39. Outside-unshielded burns by degree for Hiroshima.

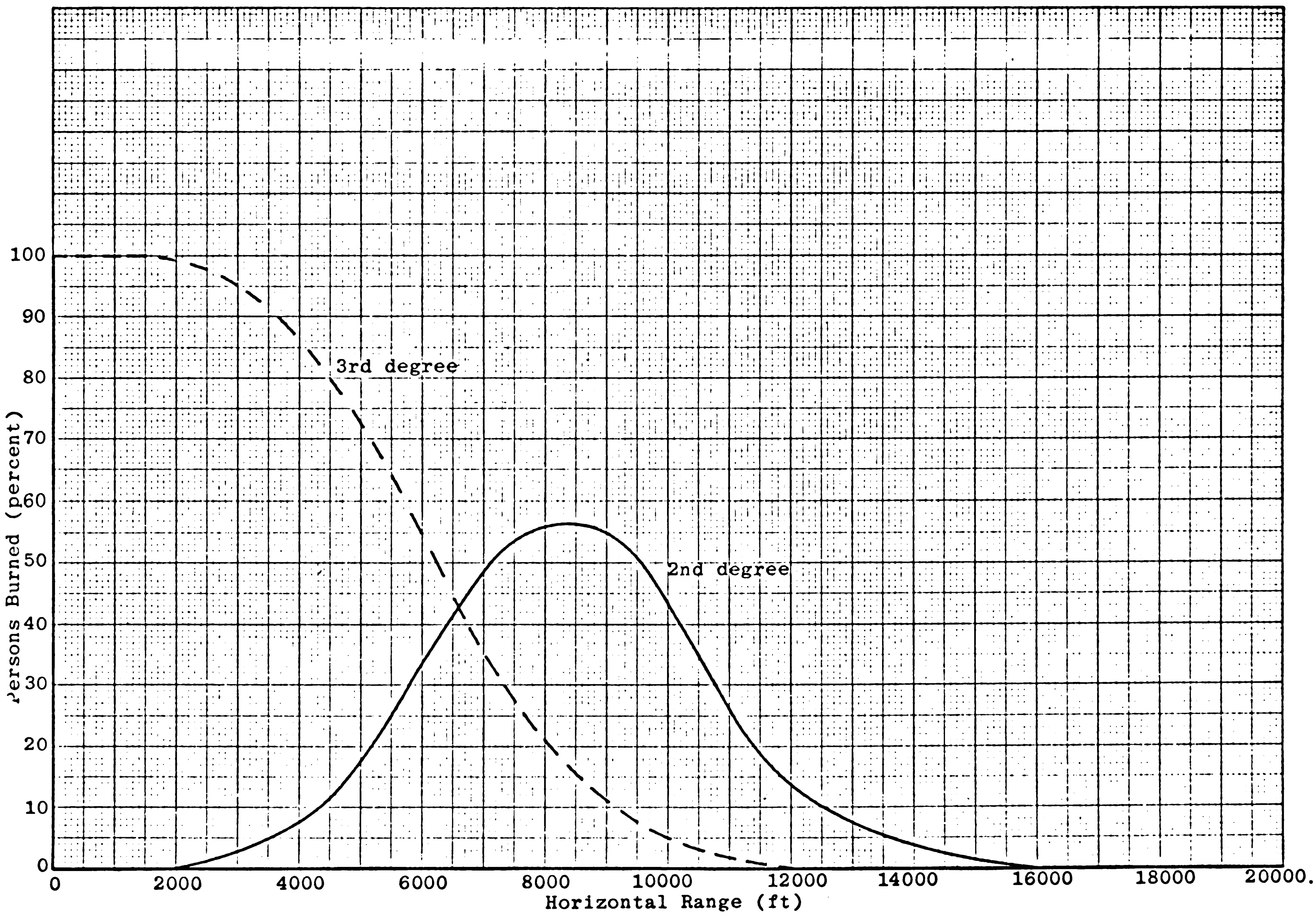

Figure 40. Outside-unshielded burns by degree for Nagasaki.

mutually exclusive injury combinations were dominant for outside-unshielded persons. These five combinations were as follows: moderate prompt-thermal injuries only, severe prompt-thermal injuries only, moderate initial-nuclear and moderate prompt-thermal injuries, severe initial-nuclear and moderate prompt-thermal injuries, and moderate blast injuries only. Combined injury curves for five building or shielding categories (seismic reinforced-concrete, nonseismic reinforced-concrete, light steel-frame, wood-frame, and outside-shielded by buildings) are given in Figures 41 through 45, while the outside-unshielded curves are presented in Figure 46. Only data from Hiroshima were sufficient to define injury combinations.

It should be noted that these injury combinations are strictly applicable only to that particular nuclear device used over Hiroshima. Scaling these injury combinations to other yields is a complicated matter. This complexity is due to the fact that each weapon effect requires the use of different scaling procedures. Scaling these data to high yields (1 MT and above) is discussed in Reference 3. However, scaling these data to lower yields (less than the 12.5 KT for Hiroshima) is more difficult and will require considerable additional analysis of these and other data before this is feasible. Scaling these data to yields between 12.5 KT and 1 MT is nearly as complicated as scaling them to the lower yields mentioned above. Analysis, important data characteristics, and methodology for scaling to high yields are all addressed in more detail in Reference 3.

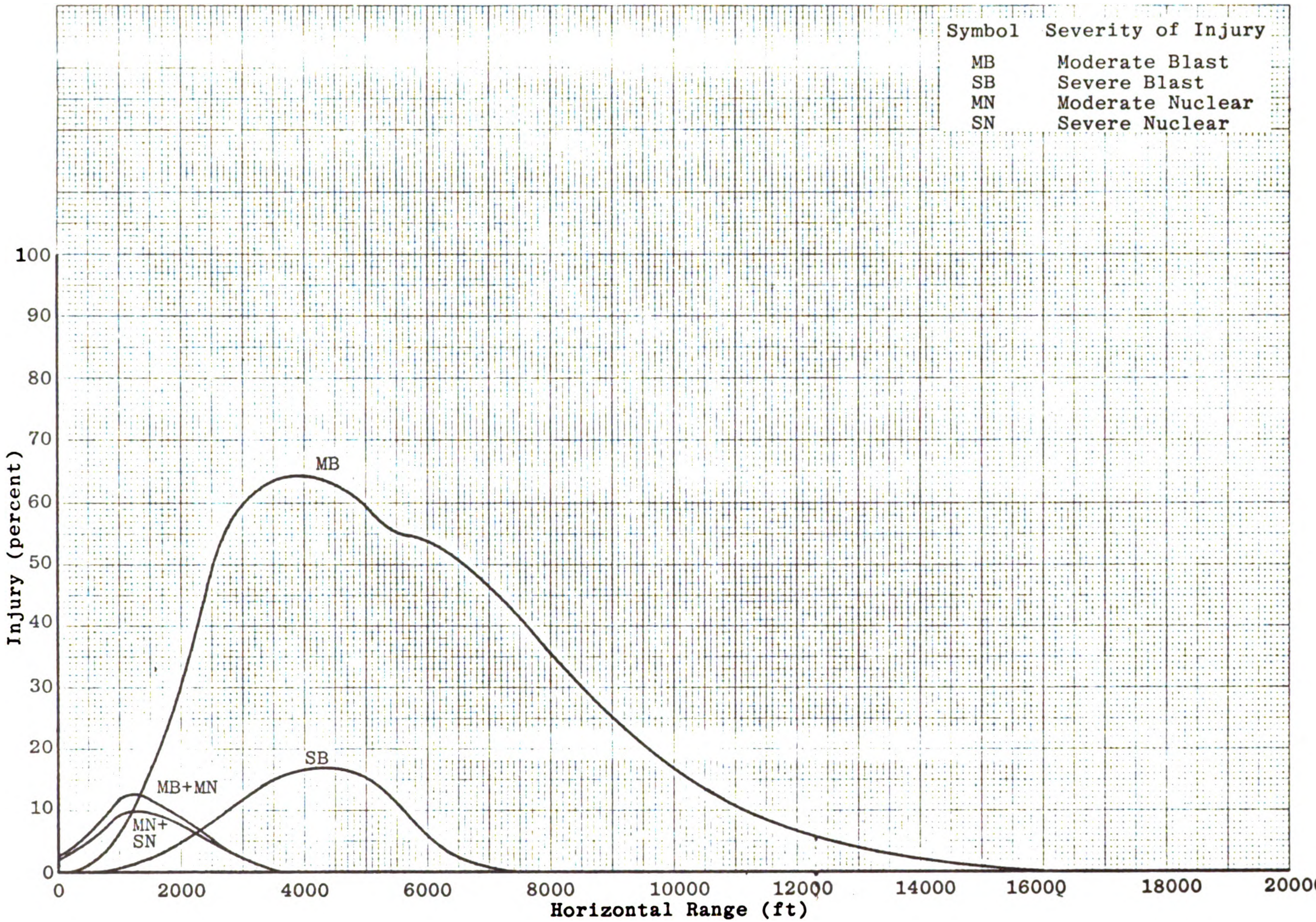

Figure 41. Hiroshima injury combination curves for seismic reinforced-concrete buildings.

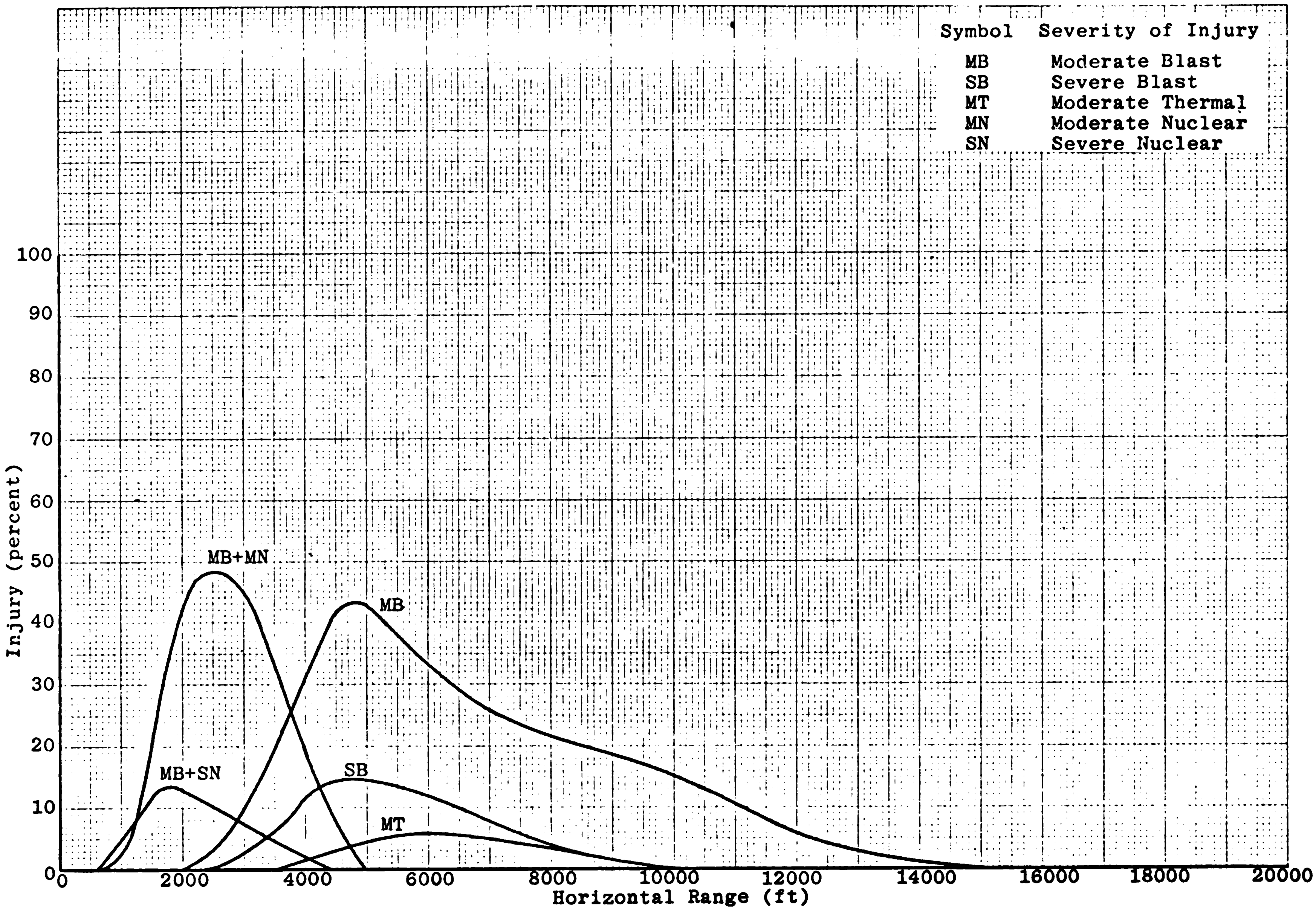

Figure 42. Hiroshima injury combination curves for nonseismic reinforced-concrete buildings.

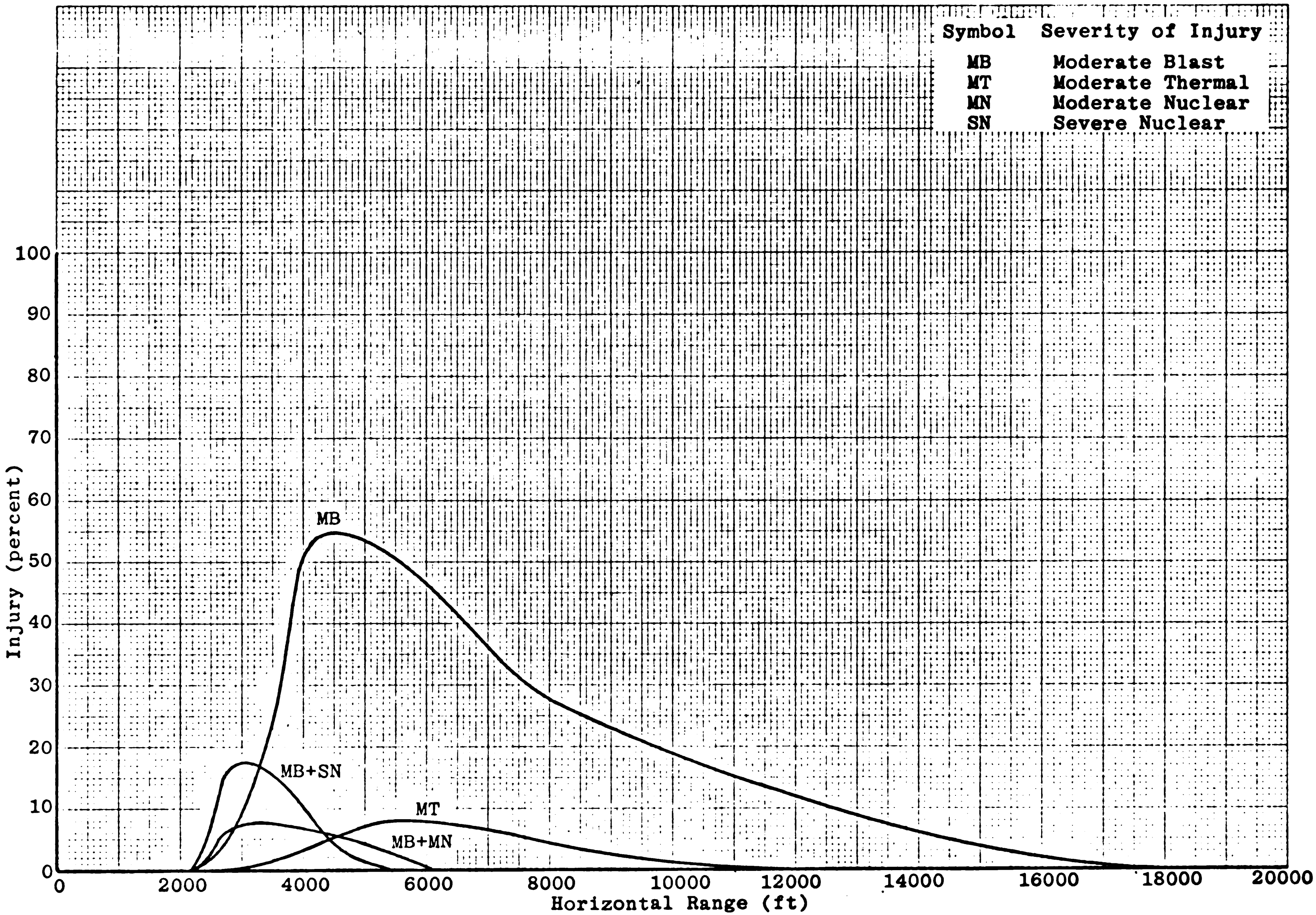

Figure 43. Hiroshima injury combination curves for light steel-frame buildings.

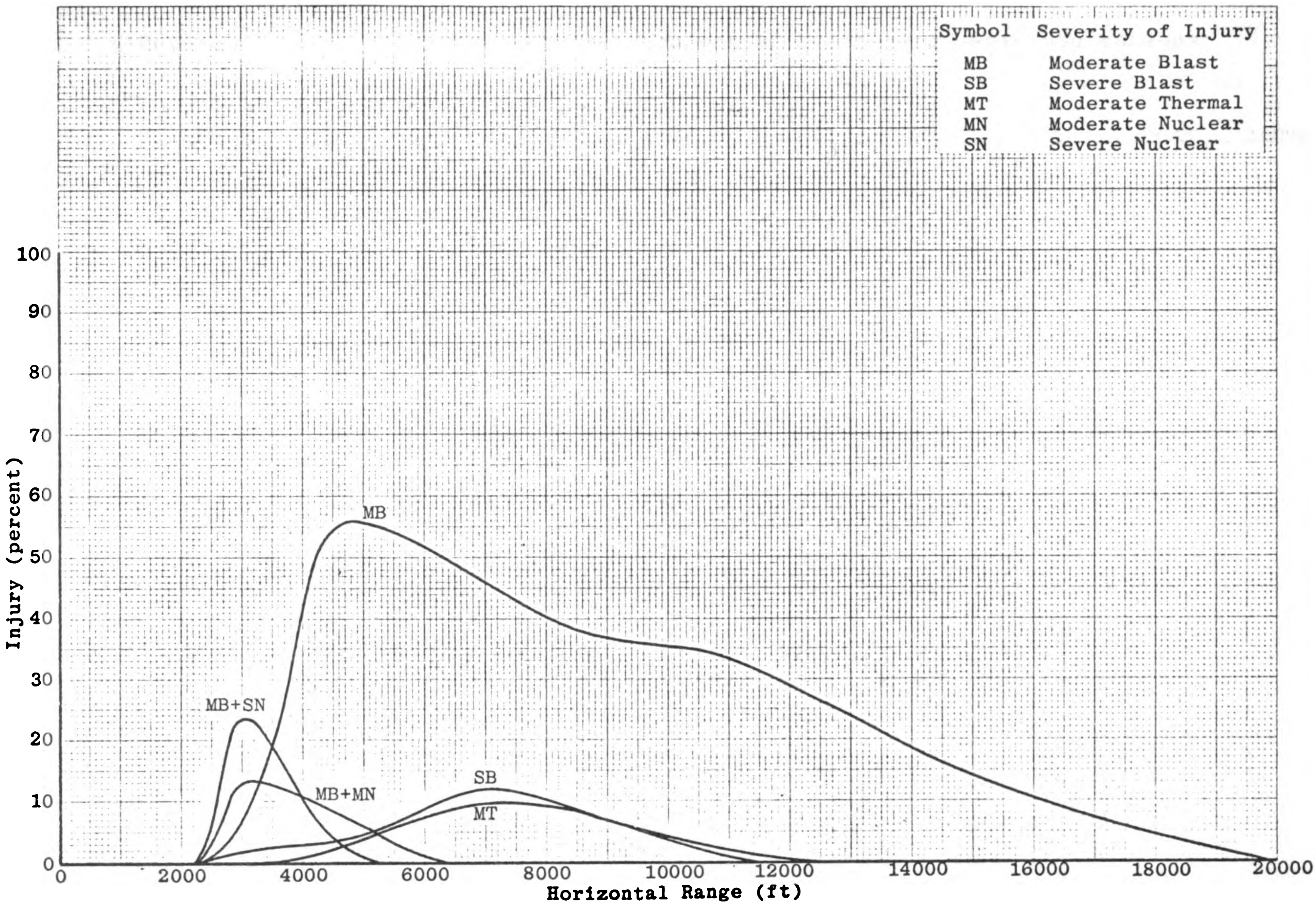

Figure 44. Hiroshima injury combination curves for wood-frame buildings.

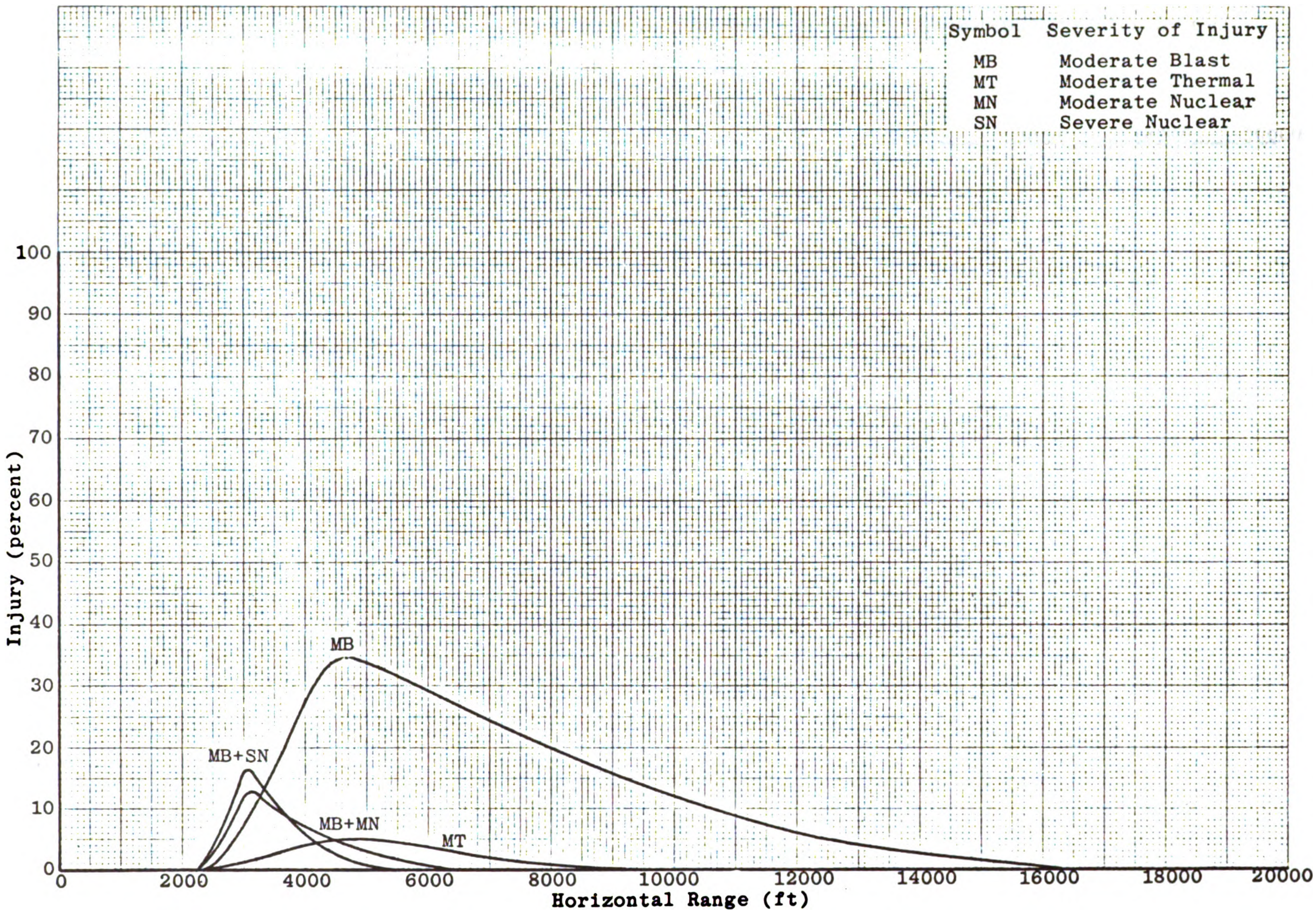

Figure 45. Hiroshima injury combination curves for outside-shielded persons.

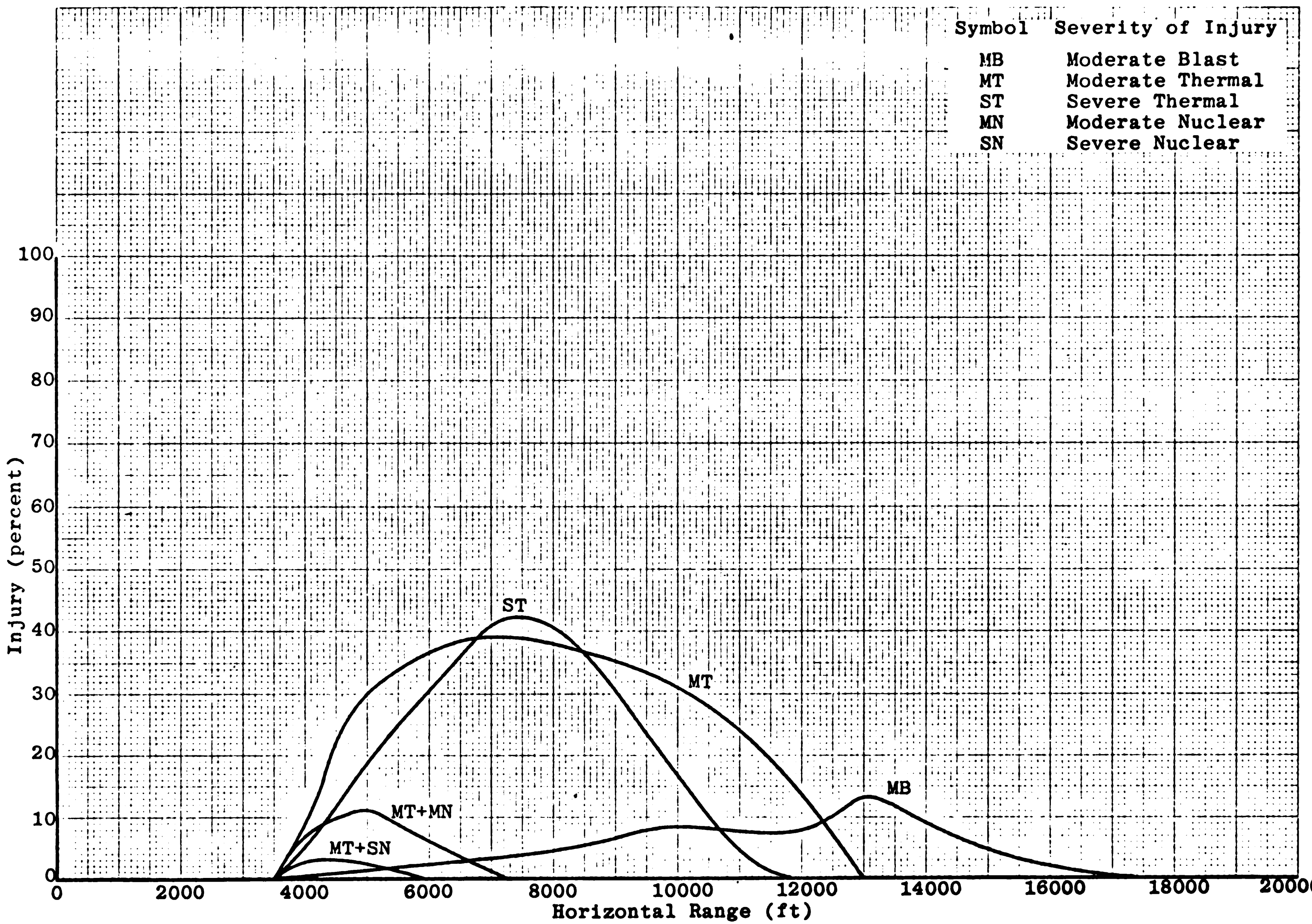

Figure 46. Hiroshima injury combination curves for outside-unshielded persons.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5-1 APPLICABILITY OF DATA

From a rigorous and strict standpoint, all of the Japanese data presented in this report are applicable only to the weapons and burst conditions present in Japan. However, using appropriate scaling methodology, some of these data have applicability to other burst conditions and yields for nuclear weapons of the same basic conventional design. For detailed scaling methodology applicable to 1 MT or larger yields, see Reference 3. The casualty data presented in this report are all compatible with the presentations and treatment used in the reference documents.

5-2 FREE-FIELD NUCLEAR WEAPON EFFECTS COMPATIBILITY

The nuclear weapon effects parameters used in this report which are applicable to the weapons used in Japan are those contained in References 2 and 3. The most recently accepted Japanese nuclear weapon effects parameters (see Table 1) are essentially the same as those used in the reference documents. Consequently, no significant errors are introduced by using the parameters given in Reference 2.

5-3 RELEVANCE TO OTHER DATA

These casualty data are compatible with and complimentary to the initial-nuclear-radiation data given in Reference 7 since they are all derived from the same Japanese data sources. This data compilation provides a convenient single source for the Japanese casualty data that were previously contained in several documents of somewhat limited distribution. This part of the report contains only Japanese casualty data. This was done to keep the report concise and unclassified, thus enhancing the availability of this material. Discussions have been kept purposely brief since more detailed information is given in the reference documents.

PART II
CASUALTY DATA FROM TEXAS CITY

CHAPTER 1
INTRODUCTION

1-1 ORIGIN OF DATA SOURCES

While docked in the Texas City harbor (near Galveston, Texas) the SS Grandcamp unexpectedly and violently exploded at about 9:15 A.M. on April 16, 1947, killing and injuring a large number of people. A second ship docked some 650 feet from the first, the SS Highflyer, was set afire by this explosion and it too exploded some 16 hours later. The explosion of the second ship complicated the data reduction, but the casualties caused by the second explosion were minimal since this explosion was anticipated. Only casualties resulting from the explosion of the SS Grandcamp were used in the analysis of the disaster.

The explosive agent was, apparently, 880 tons of ammonium-nitrate fertilizer stored in hold No. 4 of the SS Grandcamp. It was apparently set off by a fire discovered in that hold about an hour before the explosion. The explosive force was equivalent to that of a nuclear detonation with a yield of about 0.67 KT.

1-1.1 Raw Data Sources

The Texas City casualty data came from three sources. The prime source was the records obtained from Drs. Truman G. and Virginia Blocker of the John Sealy Hospital (University of Texas Medical Center) in Galveston, Texas. Between 600 and 800 of the some 3,000 casualties generated by this disaster were treated at this hospital. At the time of the disaster, Dr. V. Blocker surveyed not only the patients entering this hospital, but she also sent medical questionnaires to victims outside this hospital. Furthermore, a ten-year follow-up study was also made by Dr. V. Blocker. All of these data were summarized on index cards, which were microfilmed by Dikewood in the early 1960's. The majority of the Texas City casualty data was obtained from these records. The records of the two major employers in the dock area provided additional data. The Monsanto Chemical Company and the Texas City Terminal Railway Company sustained most of the personnel and property losses in the disaster area.

Apparently some, if not all, of the original records collected by the Blockers have subsequently been destroyed. Consequently, the records at Dikewood are apparently the only remaining complete set of raw data for this event with the possible exception of a small amount of data that may still be available from the Monsanto Chemical Company and the Texas City Terminal Railway Company records. Of course, as noted above, the casualty data from these two companies are also available at Dikewood.

1-1.2 Dikewood Data Analysis

Casualty data collected from the three sources discussed above were analyzed at Dikewood. The blast casualty curves produced by this analysis are given in Appendix B of Reference 3. The shielding categories used in this casualty analysis were essentially the same as those used in the analysis of the Japanese data given in Part I of this report. Thus, casualty data for any shielding category may be directly compared between the two types of explosions once they have been scaled to the same yield. (For scaling methodology details see Reference 3). It should be noted that the Texas City casualty data presented here are due only to blast effects, while other nuclear weapon effects were present in the Japanese data.

The coding format used to record the Texas City casualty data was essentially identical to that used for the Japanese data (see Appendix A of Reference 1 for details), except that 29 more items were added. These latter items were added as more detailed information was available from the Texas City records than was the case for Japan. It should be noted that casualties caused by large missiles (fragments of the ship) were removed from the data analysis to the fullest extent possible.

1-2 REPORT OBJECTIVES

As for the data presented in Part I, the principal objective of this part of the report is to collect additional casualty data applicable to nuclear weapons into a single concise report. Since the graphical data presented here is accompanied only by brief explanatory remarks, reference should be made to Appendix B of Reference 3 for additional details.

1-3 ORGANIZATION

This part of the report is organized similarly to that used for the Japanese data presented in Part I. Hence, the next chapter presents the free-field explosive effects predicted to be present in Texas City. Due to the smaller amount of data present for Texas City (blast casualties for only one event), Chapter 3 gives both mortality and injury casualty data for Texas City. The last chapter presents a brief summary of the conclusions and recommendations applicable to the Texas City casualty data.

CHAPTER 2

FREE-FIELD EXPLOSIVE EFFECTS

2-1 GENERAL DATA

The principal explosive was 880 tons of 95-percent prilled ammonium-nitrate fertilizer contained in Hold No. 4 (lower) of the SS Grandcamp. Additional ammonium-nitrate fertilizer (1400 tons in Hold No. 2 (lower)) and other assorted material, including a small amount of ammunition, were also aboard this ship, but apparently did not significantly contribute to the magnitude of the explosion. An interesting feature of this explosion is the relatively long duration of the positive phase duration (seconds) of the blast wave compared to that usually associated with smaller conventional high explosive (HE) detonations (milliseconds). Consequently, the blast casualty data generated by this type of explosion is directly applicable to nuclear weapons for equivalent yields. For additional detail, Appendix B of Reference 3 should be consulted.

2-2 EXPLOSION PARAMETERS

Considerable effort was expended in the original analysis of these data by Dikewood (see Appendix B of Reference 3) to determine the equivalent TNT and nuclear yields of this explosion. Apparently, the blast effectiveness of the ammonium-nitrate fertilizer relative to TNT was slightly less than 0.4. Thus, the 880 tons of fertilizer had an equivalent TNT yield of 334 tons. Since, with respect to blast, TNT is about twice as effective as a nuclear device of the same yield, this TNT yield of 334 tons translates into an effective nuclear yield of about 0.67 KT.

Figure 47 presents the predicted peak overpressure (labeled as overpressure) in psi as a function of horizontal range in feet from the explosion. Since this is a surface burst, horizontal range is the same as slant range. This figure also gives the yield in equivalent tons of TNT (i.e., 334). When

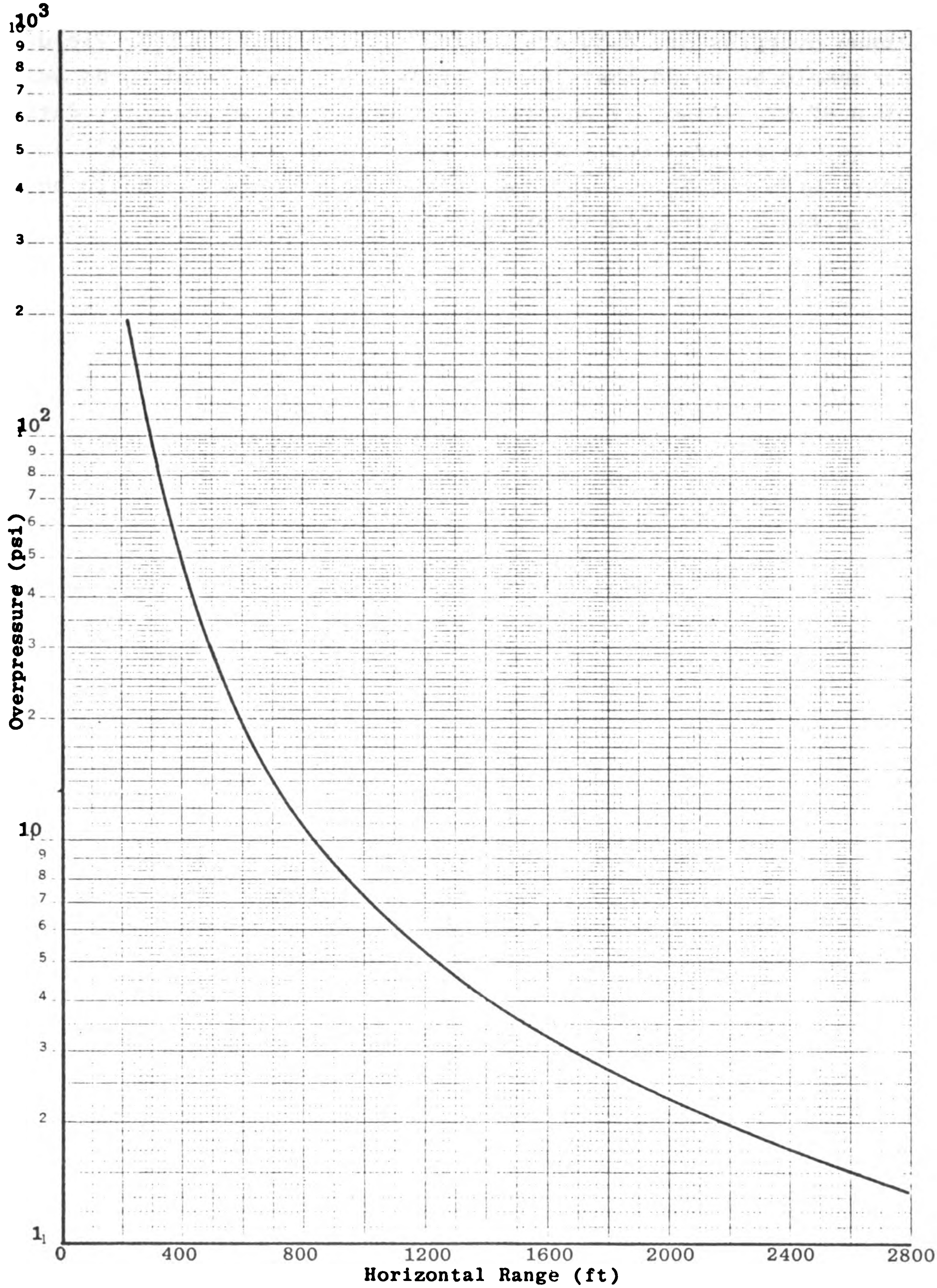

Figure 47. Predicted overpressures for Texas City disaster (334 tons TNT).

these overpressure data are scaled to different nuclear yields, it should be noted that the equivalent nuclear yield to be scaled is 0.67 KT. Also, it should be noted that blast casualty data do <u>not</u> in general scale as the cube root of the yield ($W^{1/3}$). Therefore, Chapter IV and Appendix C of Reference 3 should be consulted to determine appropriate scaling procedures.

CHAPTER 3
CASUALTY DATA

3-1 GENERAL DATA

In this chapter blast casualty data are given for the six shielding categories of nonseismic reinforced-concrete buildings, heavy steel-frame buildings, light steel-frame buildings, wood-frame buildings, outside-shielded category, and outside-unshielded category. The total mortality and injury curves include the data points coded by sample size. These shielding categories are reasonably consistent with the similar shielding categories used for the Japanese data given in Part I. The wood-frame building category here is probably most nearly comparable with the wood-frame commercial building data in Japan. Also, the heavy steel-frame buildings were industrial buildings, generally with 12-inch masonry walls, which are not directly comparable with any shielding category in Japan. Due to the relatively large number of heavier buildings in the area of interest, the people in the outside-shielded category were generally shielded by heavier structures than was the case in Japan. Since this was not a nuclear burst, there are no initial-nuclear or prompt-thermal casualties present.

The blast casualty percentages are plotted versus peak overpressure (labeled overpressure) in psi. Presenting the data in this form more readily permits scaling to other yields. However, if one is interested in converting these data to casualty percentages versus horizontal range, Figure 47 can be used to convert the overpressures to the appropriate horizontal ranges.

3-2 BLAST MORTALITY

The total blast mortality curves versus overpressure presented in Figures 48 through 53 were obtained from Figures B.2 through B.7 in Appendix B of Reference 3. Applicable Japanese data (especially at the longer horizontal ranges where blast

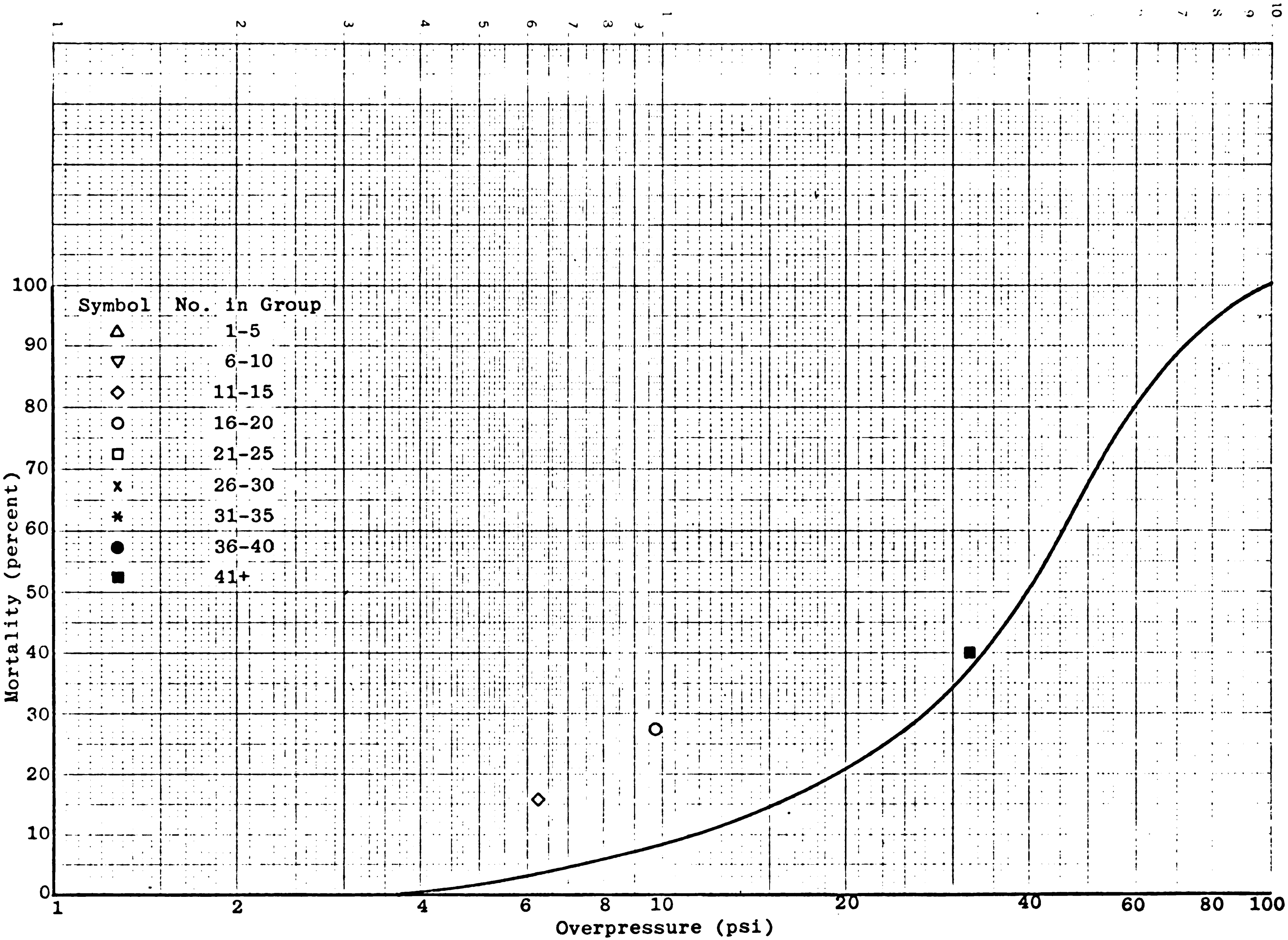

Figure 48. Texas City total mortality curve for nonseismic reinforced-concrete buildings.

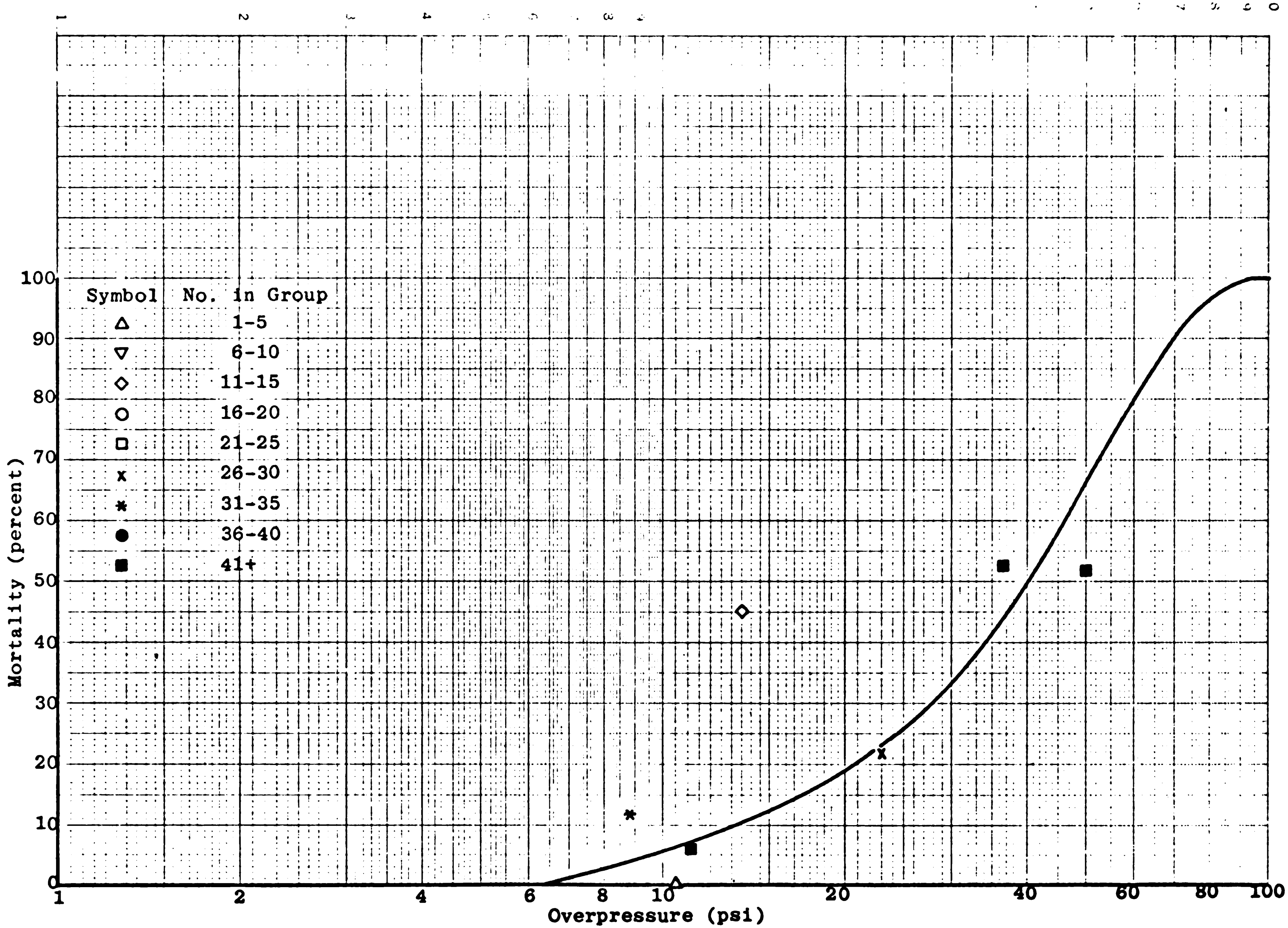

Figure 49. Texas City total mortality curve for heavy steel-frame buildings.

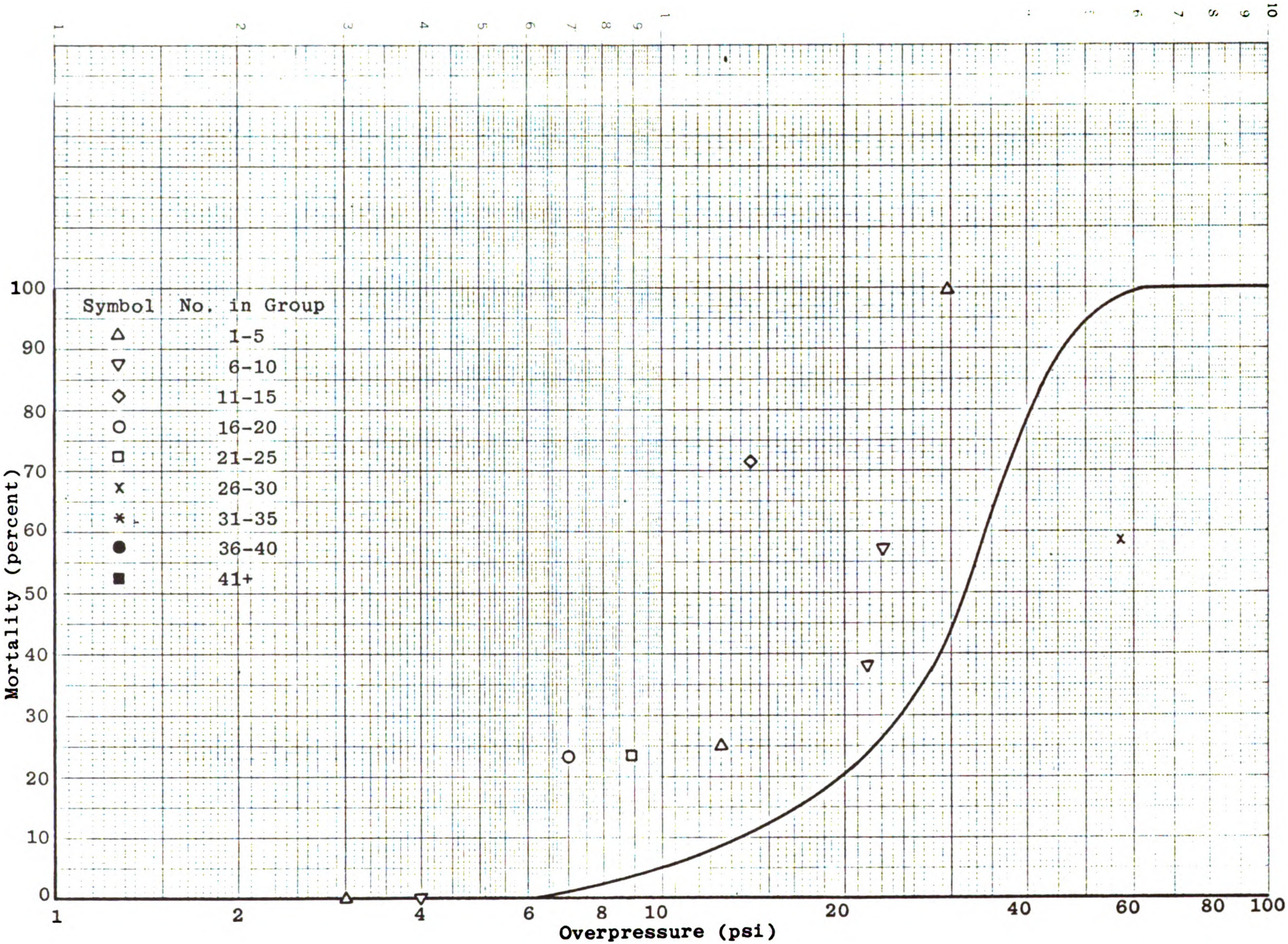

Figure 50. Texas City total mortality curve for light steel-frame buildings.

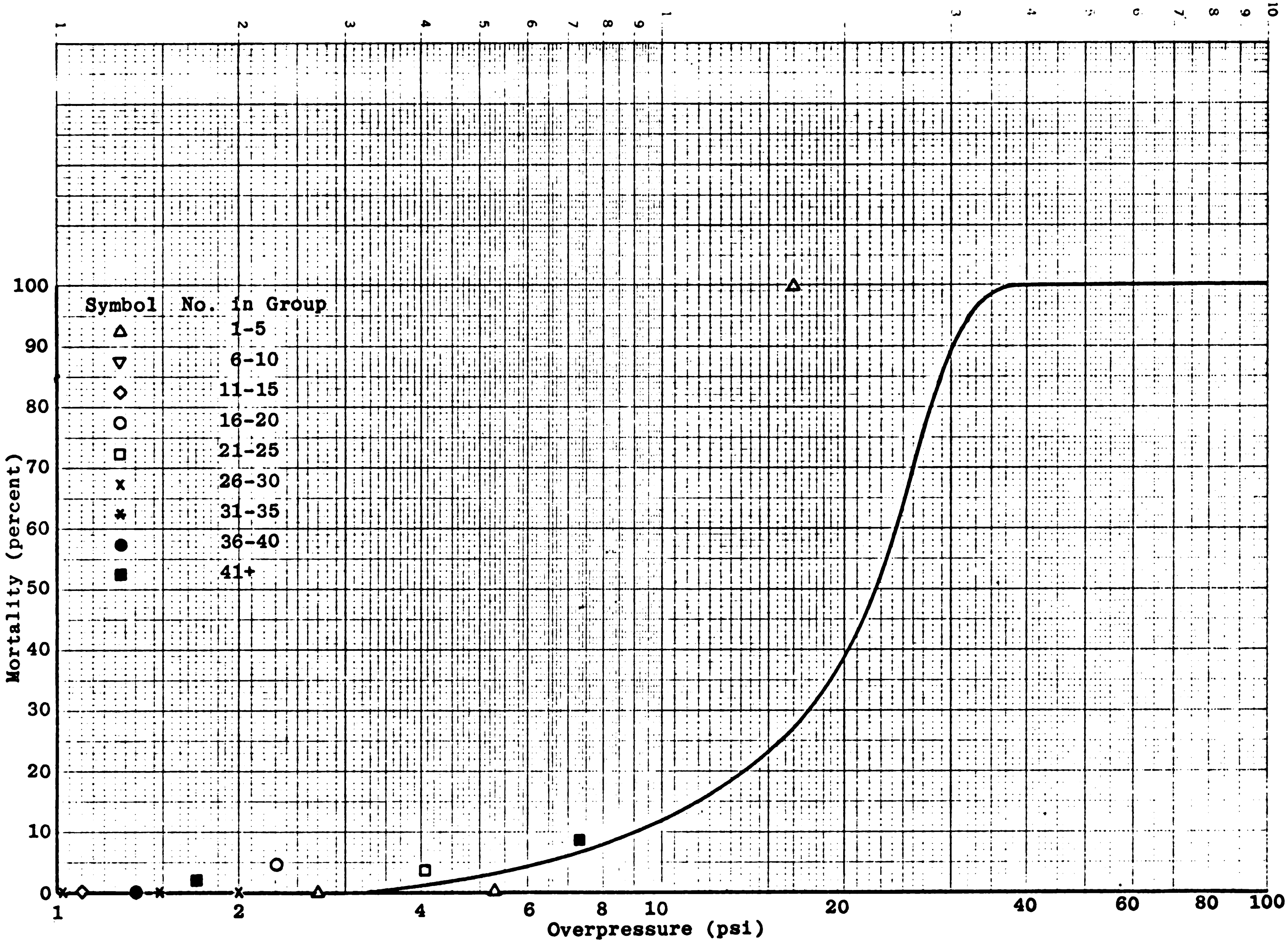

Figure 51. Texas City total mortality curve for wood-frame buildings.

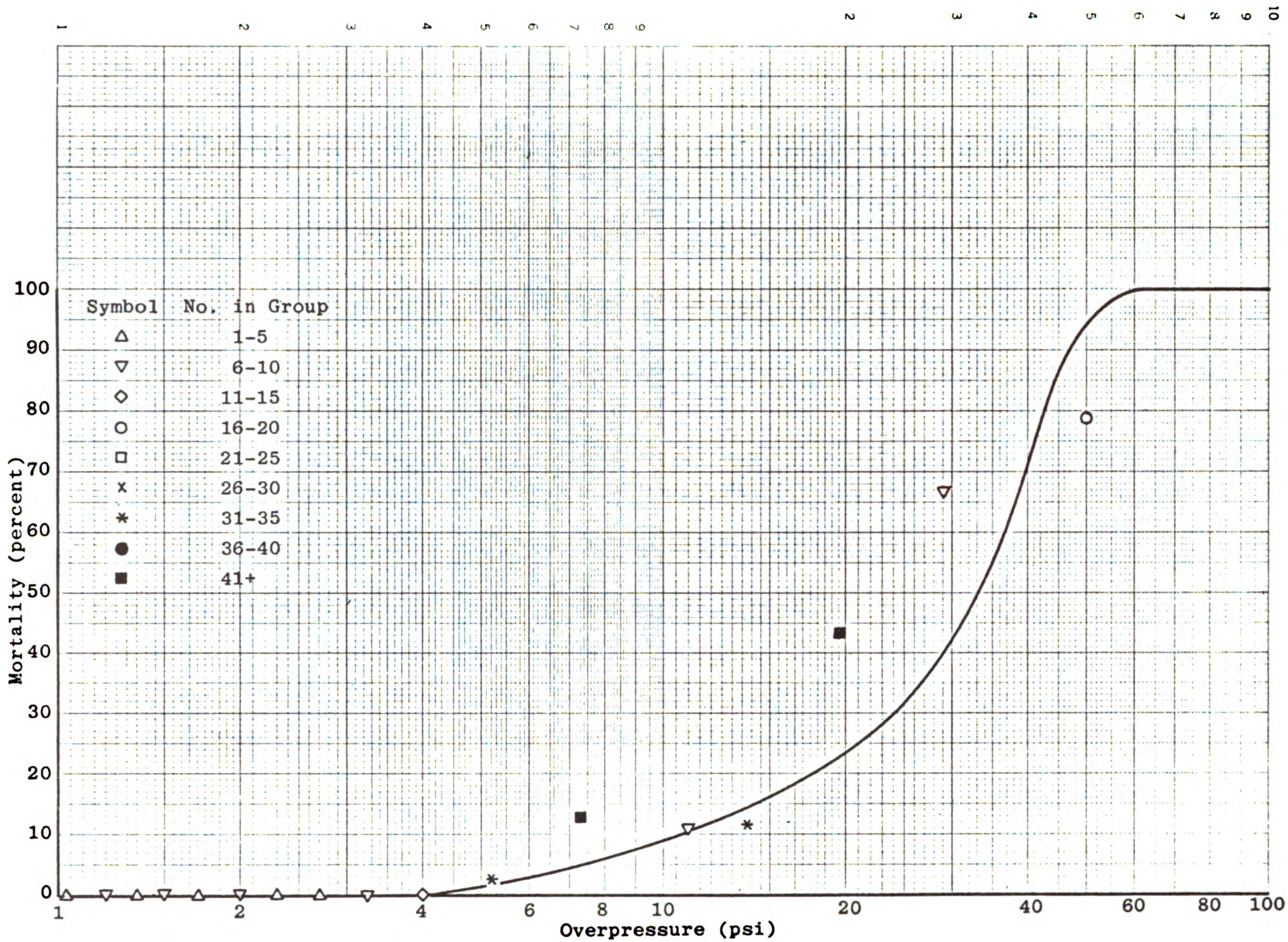

Figure 52. Texas City total mortality curve for outside-shielded persons.

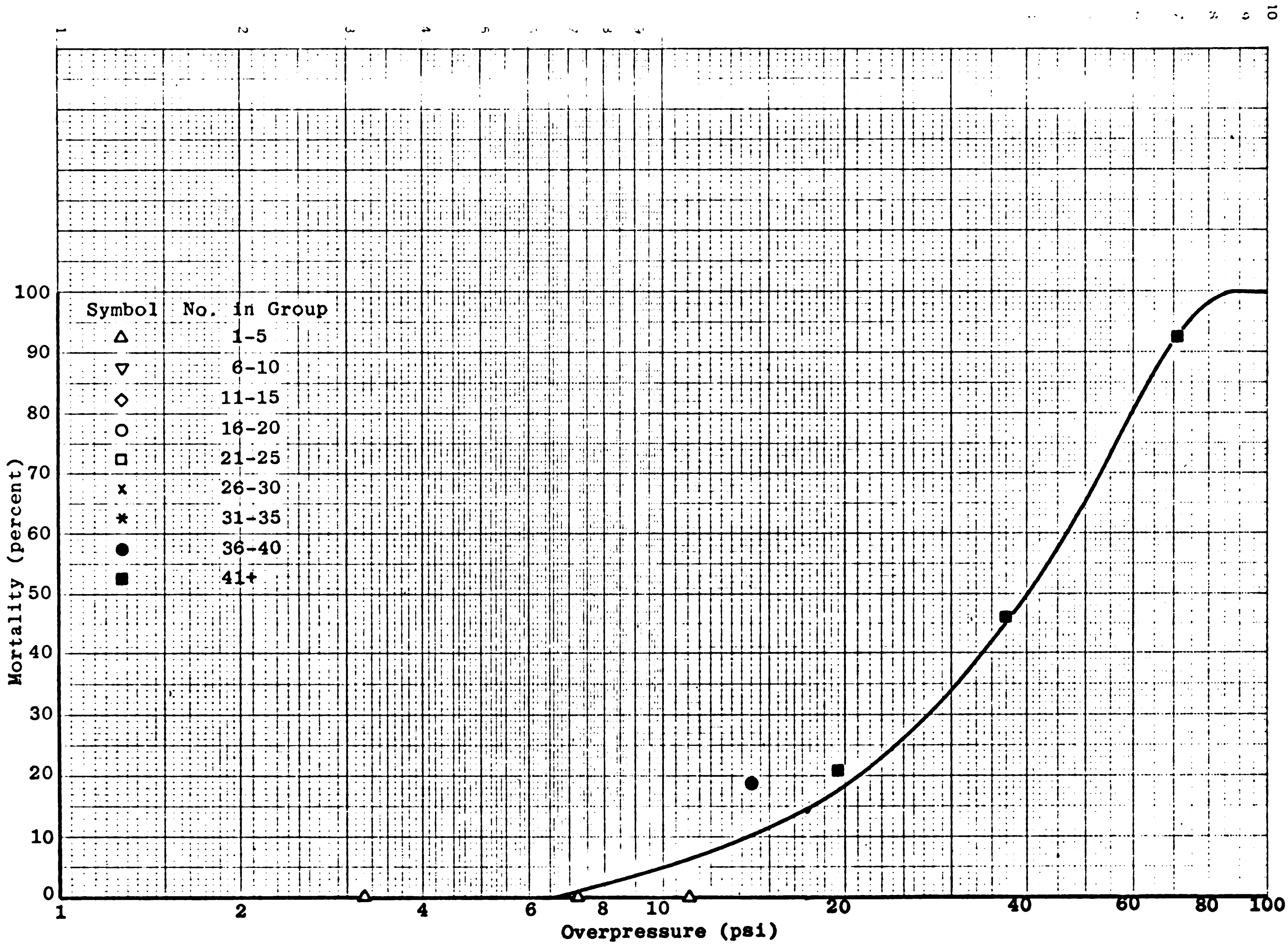

Figure 53. Texas City total mortality curve for outside-unshielded persons.

effects were dominant) and appropriate scaling procedures were also considered, in addition to the data points, in developing these curves.

The killed-immediately and mobility (i.e., ambulatory and nonambulatory) curves for each shielding category are given in Figures 54 through 59. These data were taken from Figures B.25 through B.30 in Appendix B of Reference 3. Data points are not included with these curves since three curves are presented on each figure (i.e., killed immediately, ambulatory, and non-ambulatory) and data point coding would have been too confusing. It should be noted that the killed-immediately curves are almost the same as the total mortality curves discussed previously. This result is due to the fact that fewer than 50 people died after being hospitalized, of the some 576 persons who were killed or missing (and presumed dead). Consequently, there were very few mortally injured persons in Texas City where the medical treatment for the injured was prompt, thorough, and of high quality.

3-3 BLAST INJURY

Of course, the total injury curve for a shielding category is dependent on the associated total mortality curve since persons who died were not included in the injury assessment. In addition to these mortality considerations, the total injury curves were developed using the data points and applicable Japanese data (especially at the longer horizontal ranges where blast effects were dominant) with appropriate scaling procedures. The total injury curves versus overpressure given in Figures 60 through 65 were obtained from Figures B.8 through B.13 in Appendix B of Reference 3.

The different types of blast injury curves given in Figures 66 through 76 were taken from Figures B.14 through B.24 in Appendix B of Reference 3. Data points are not included on these curves since all six shielding categories are shown for

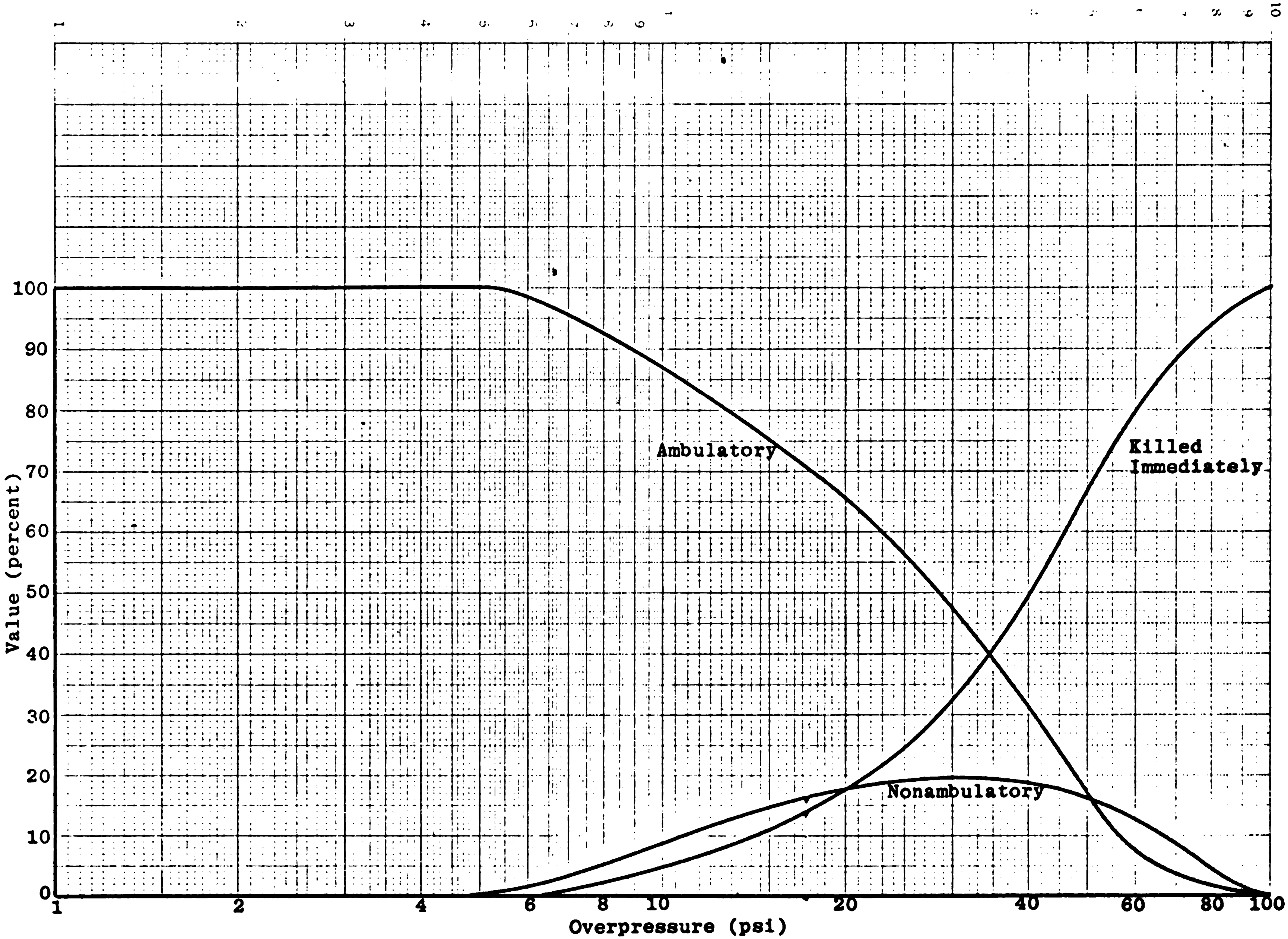

Figure 54. Mobility of exposed personnel in nonseismic reinforced-concrete buildings.

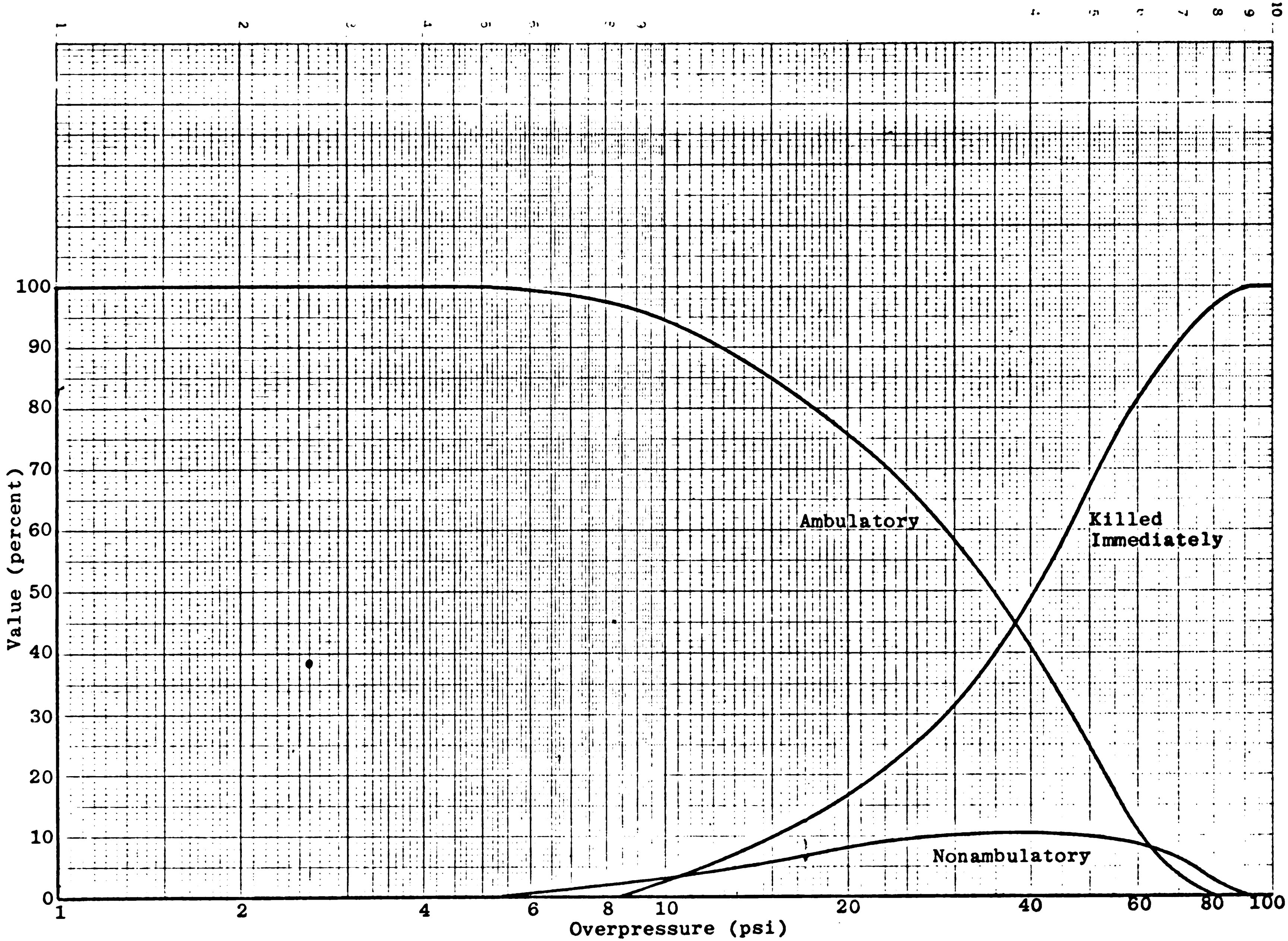

Figure 55. Mobility of exposed personnel in heavy steel-frame buildings.

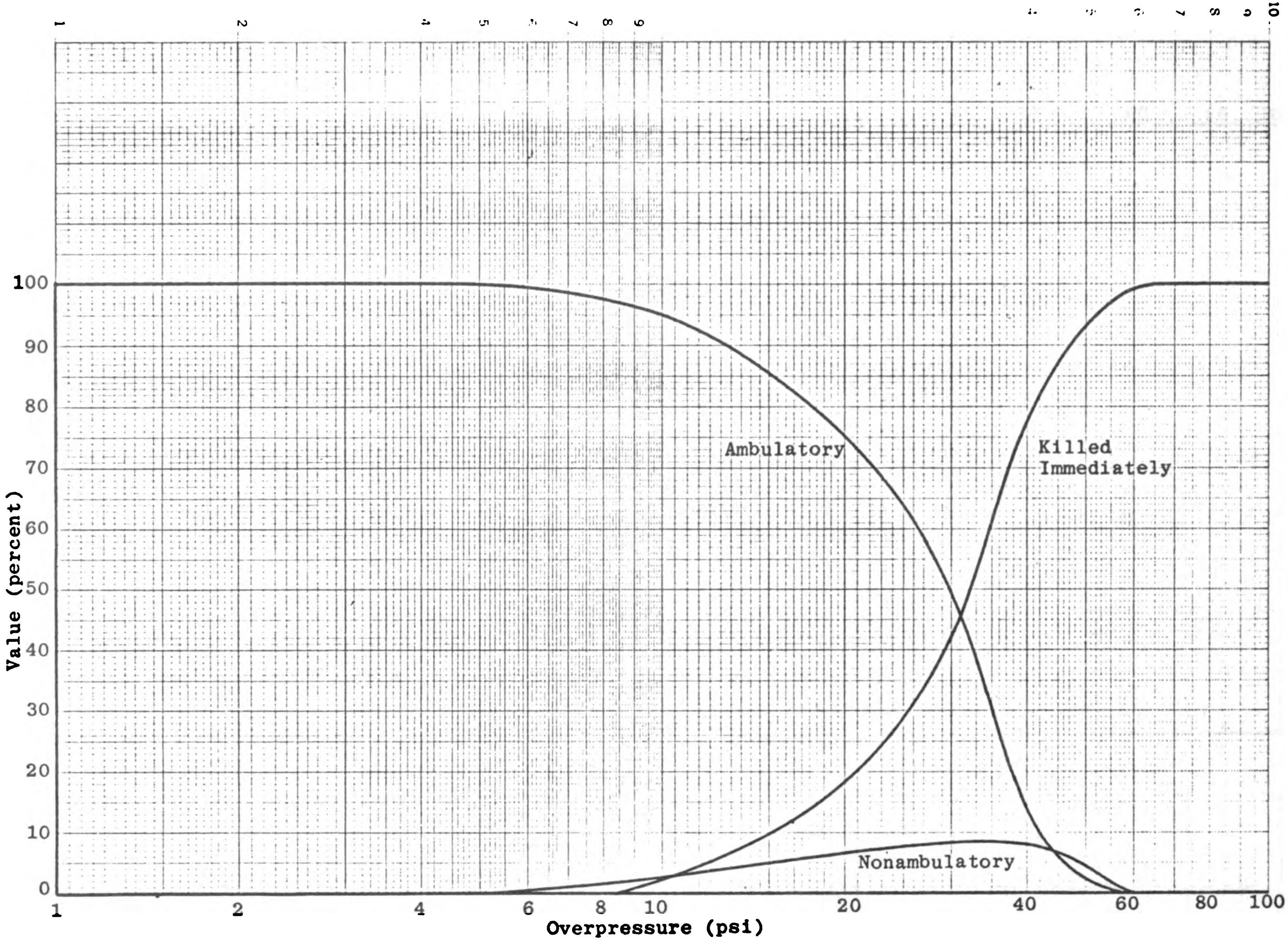

Figure 56. Mobility of exposed personnel in light steel-frame buildings.

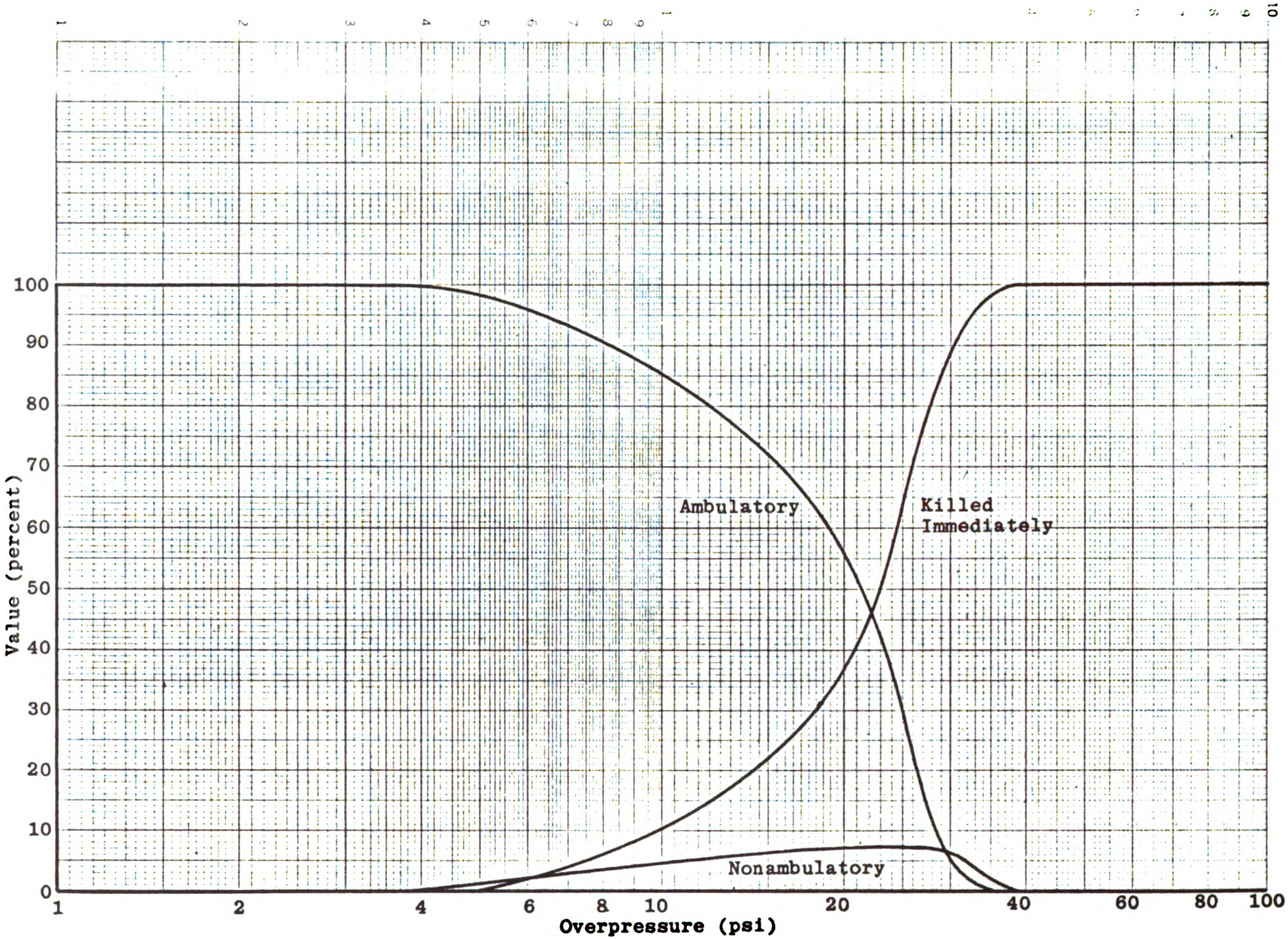

Figure 57. Mobility of exposed personnel in wood-frame buildings.

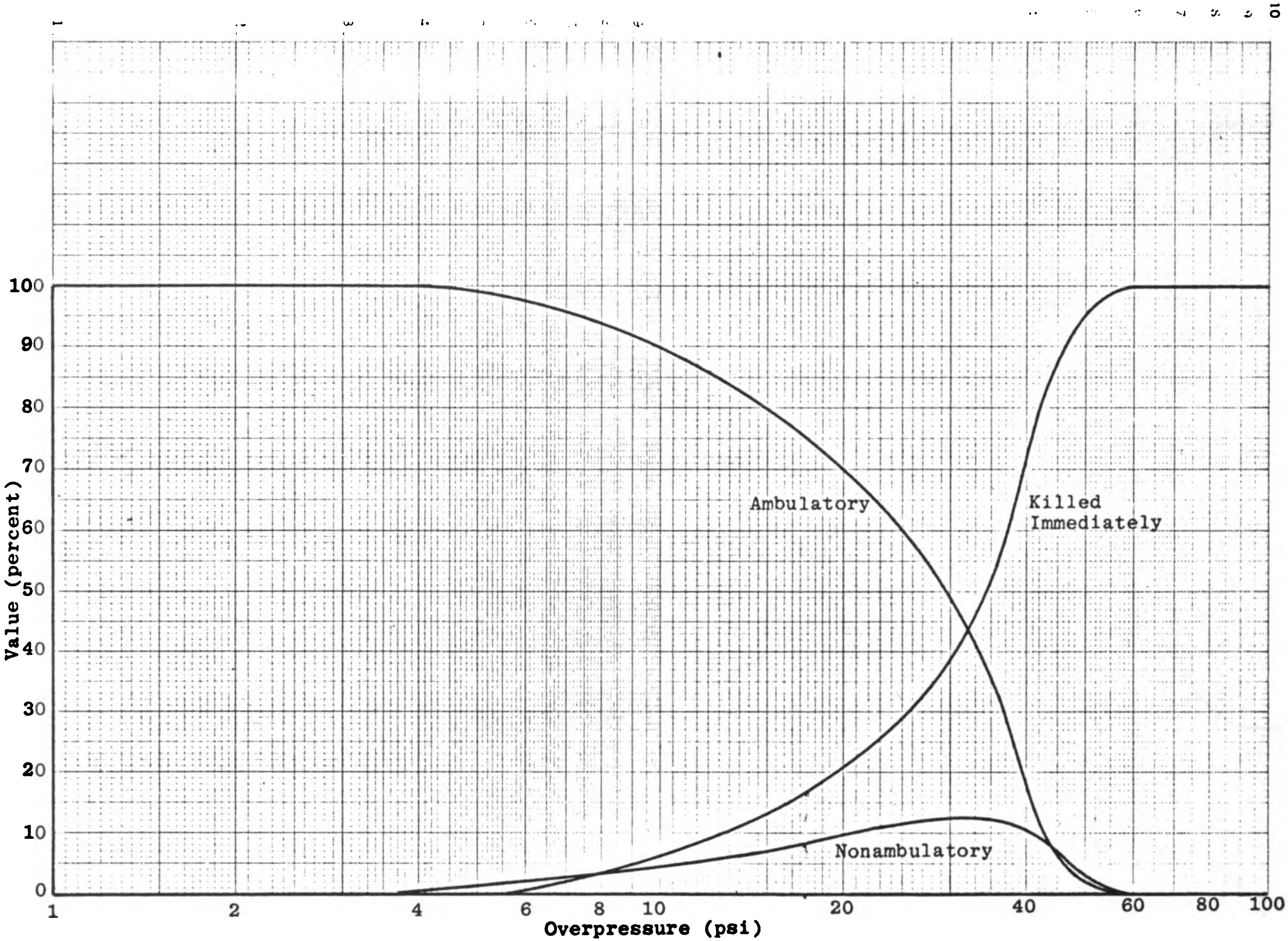

Figure 58. Mobility of exposed outside-shielded personnel.

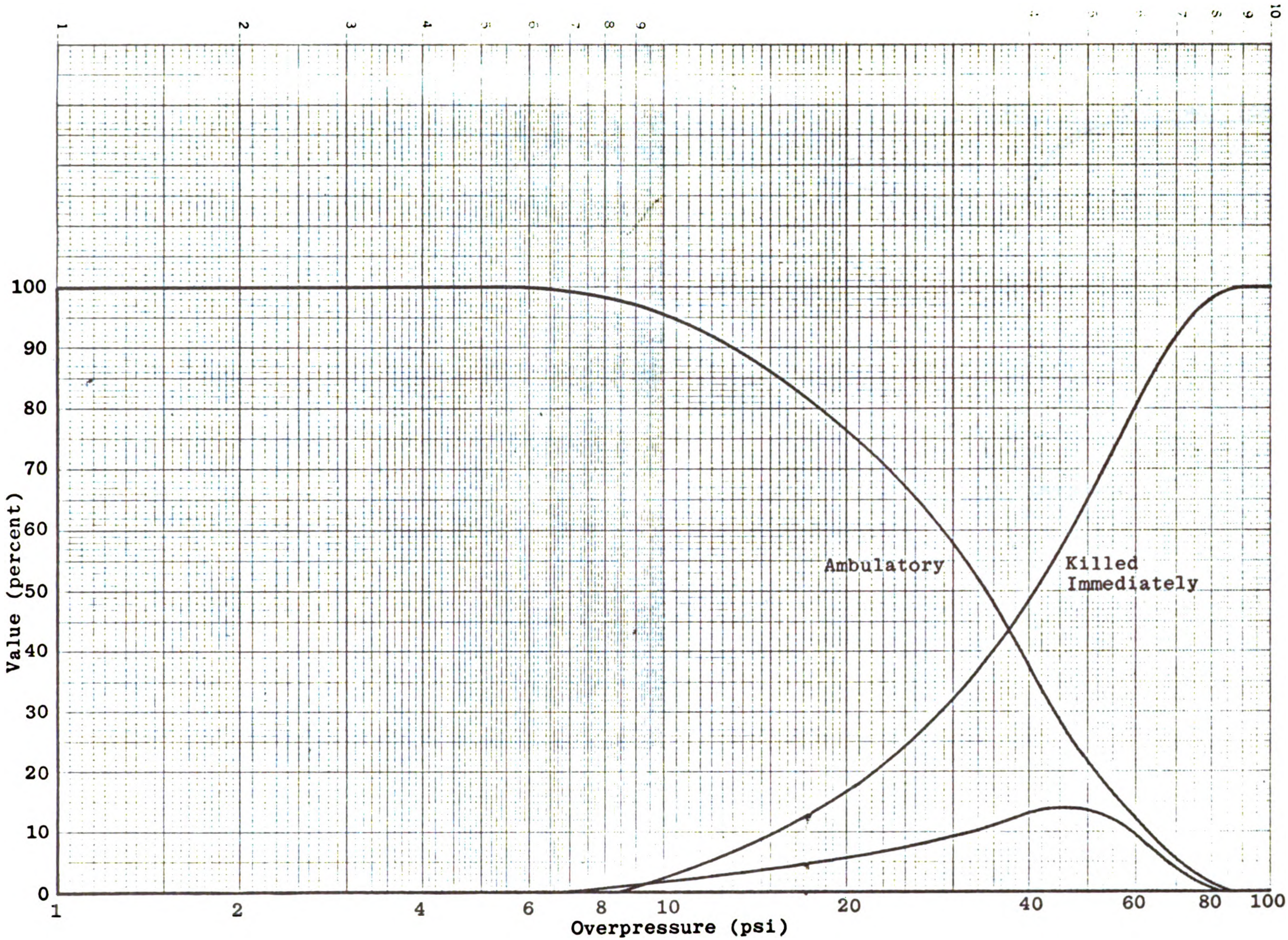

Figure 59. Mobility of exposed outside-unshielded personnel.

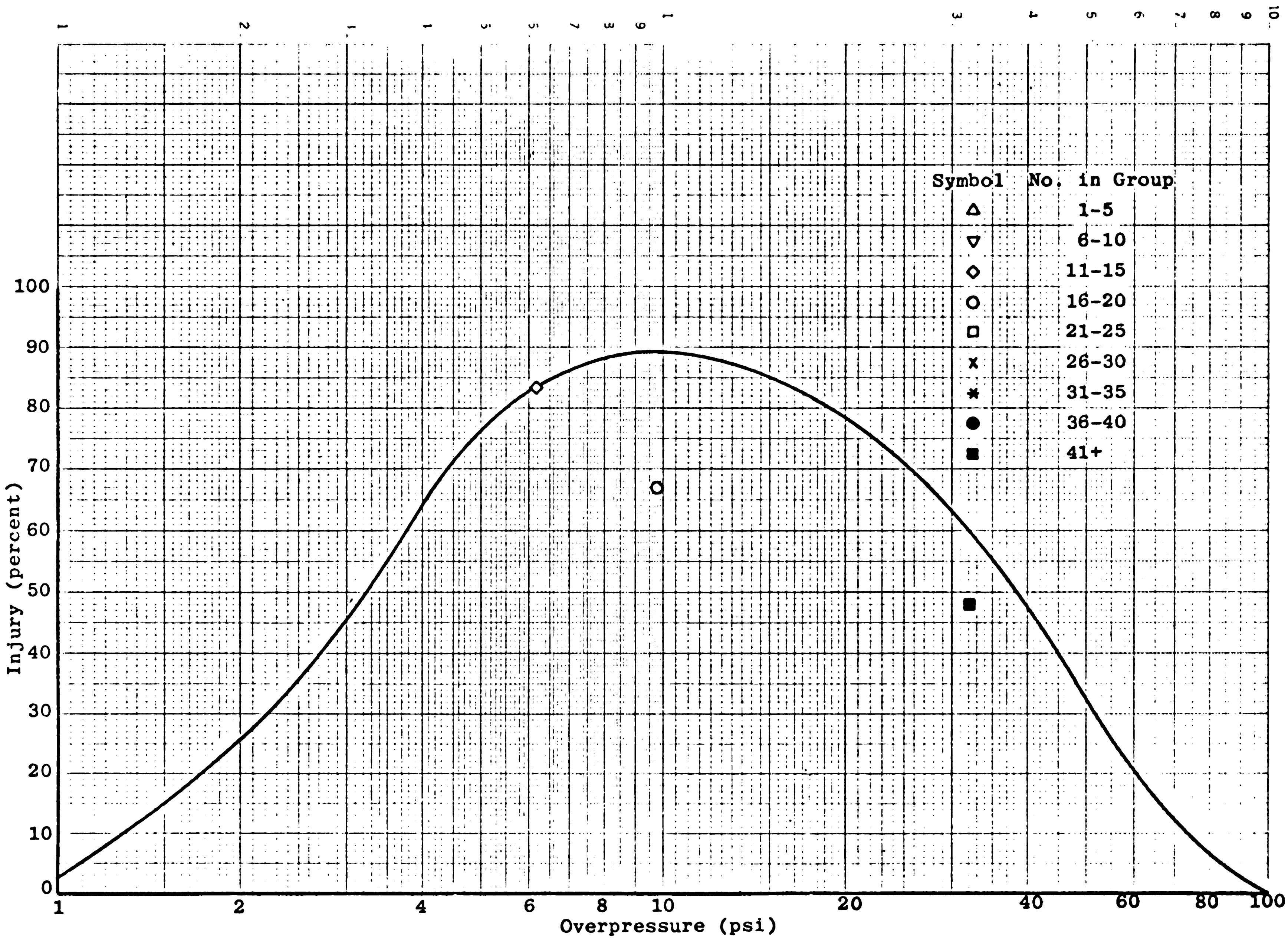

Figure 60. Texas City total injury curve for nonseismic reinforced-concrete buildings.

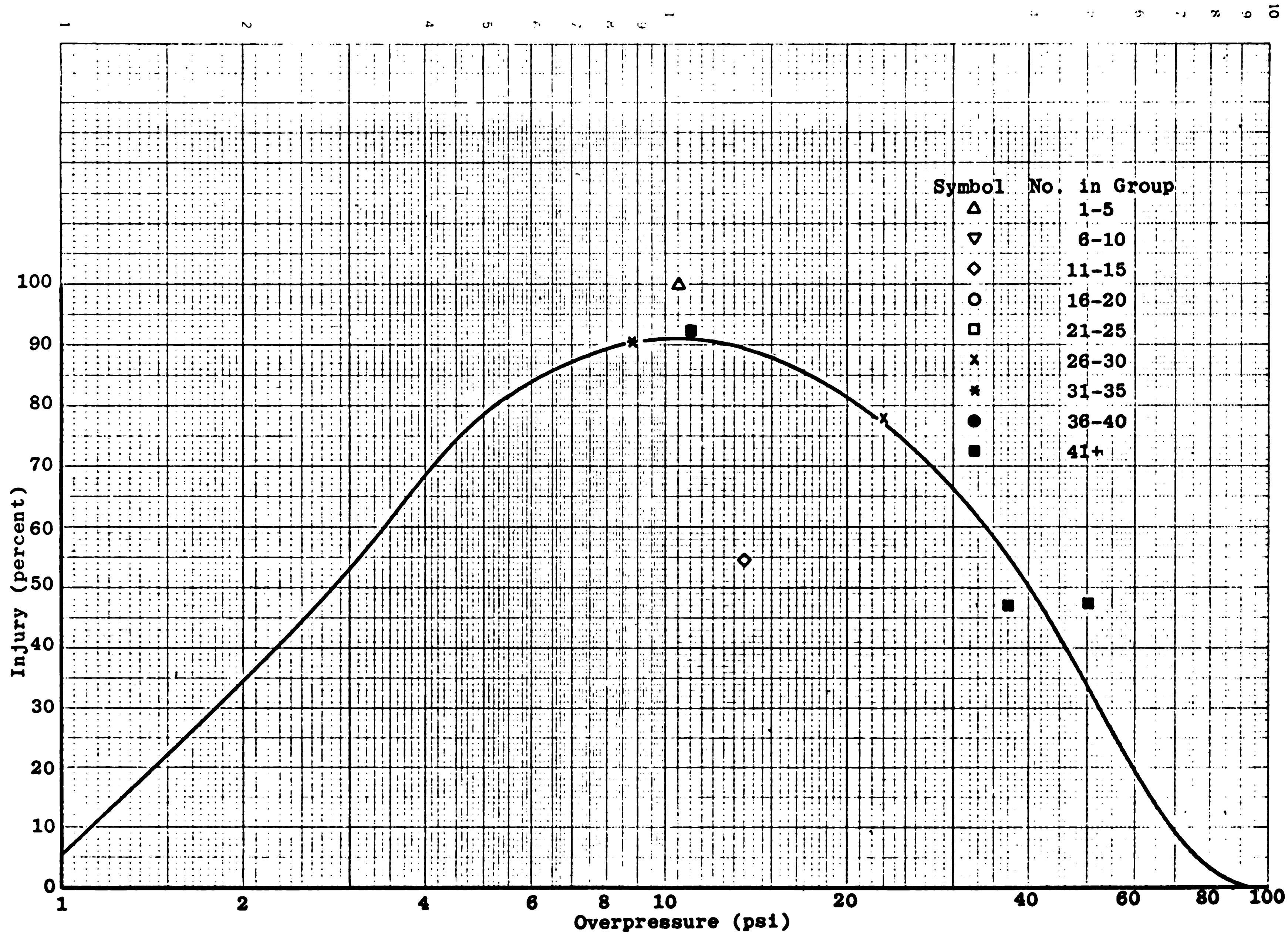

Figure 61. Texas City total injury curve for heavy steel-frame buildings.

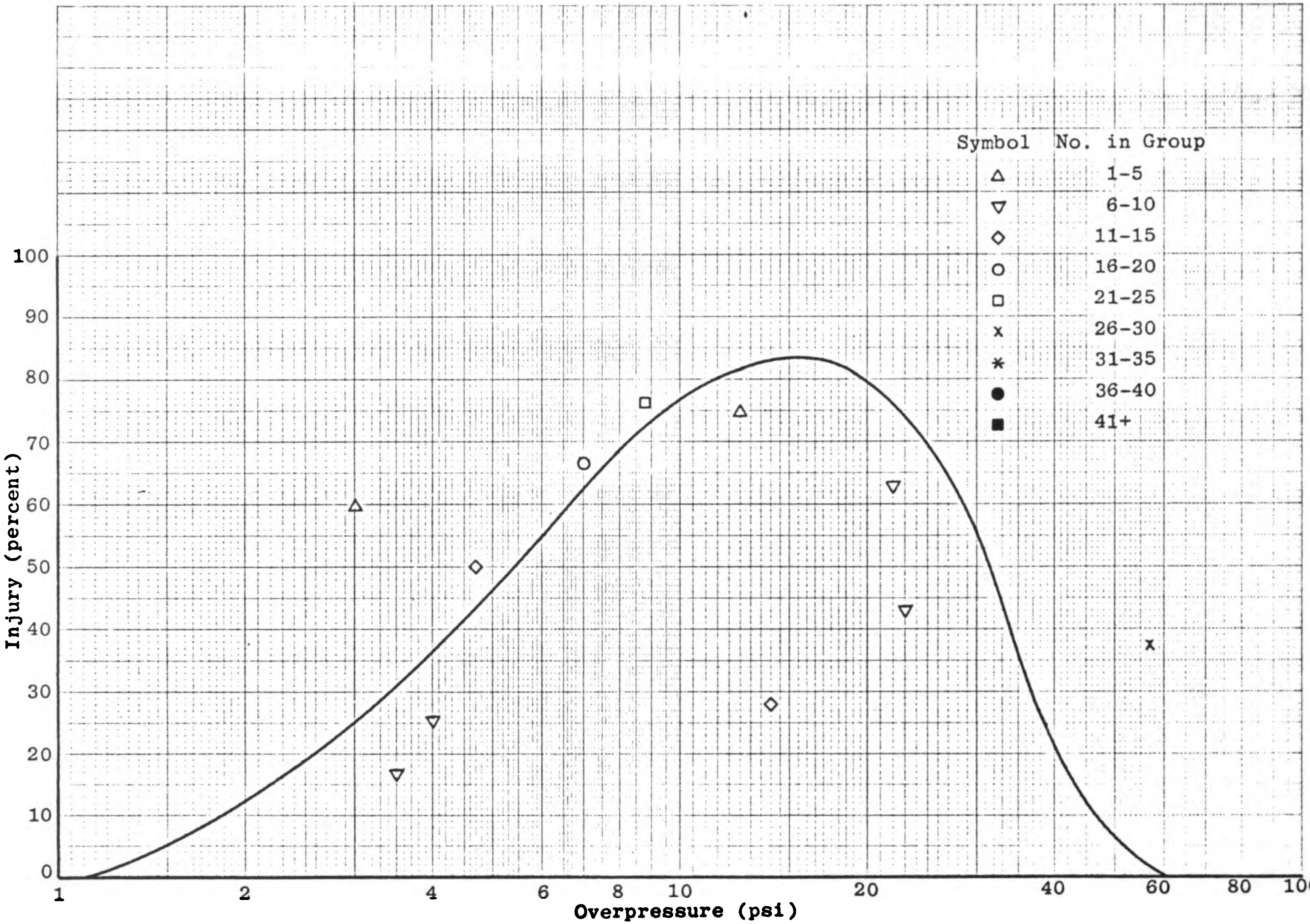

Figure 62. Texas City total injury curve for light steel-frame buildings.

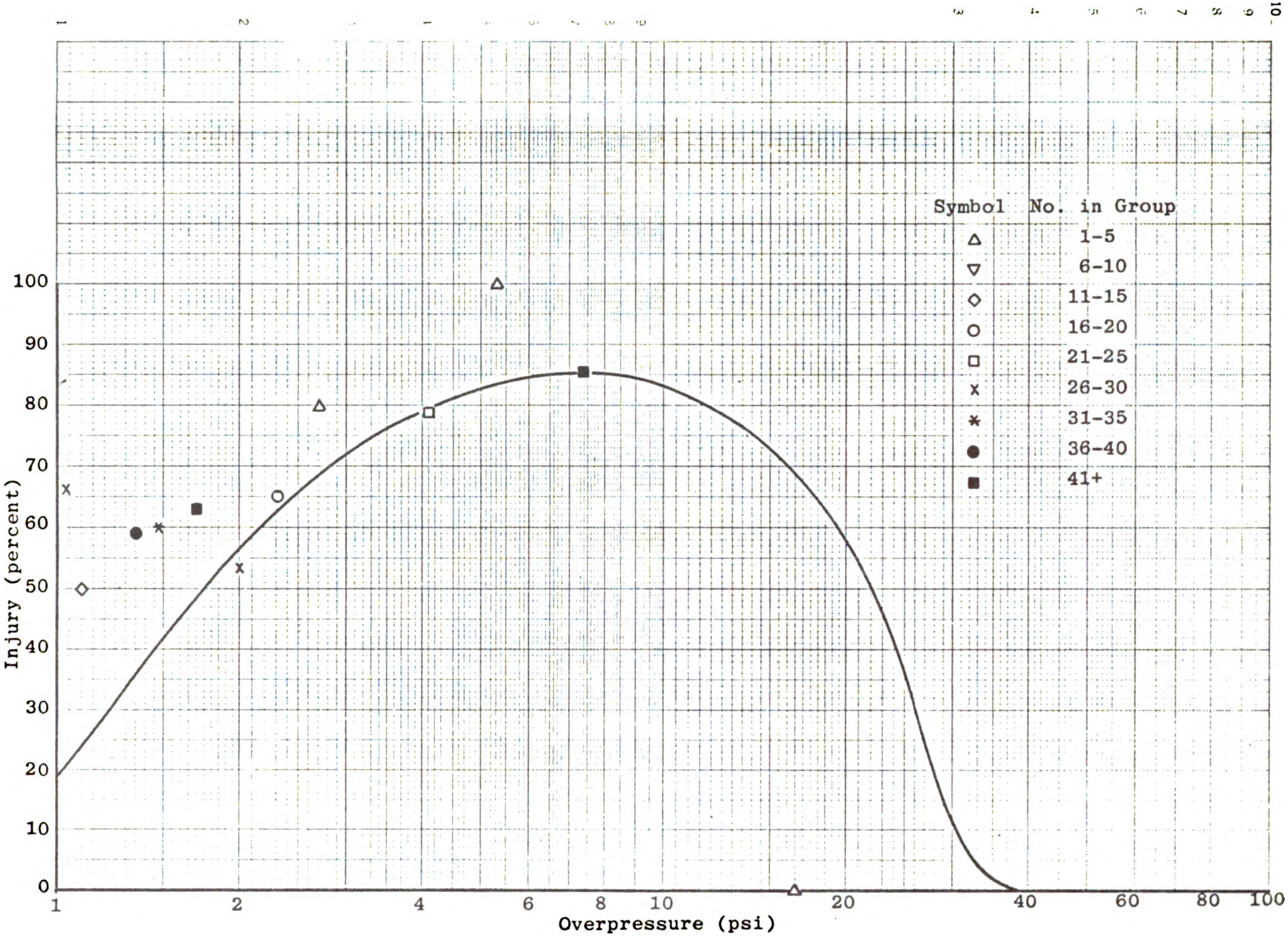

Figure 63. Texas City total injury curve for wood-frame buildings.

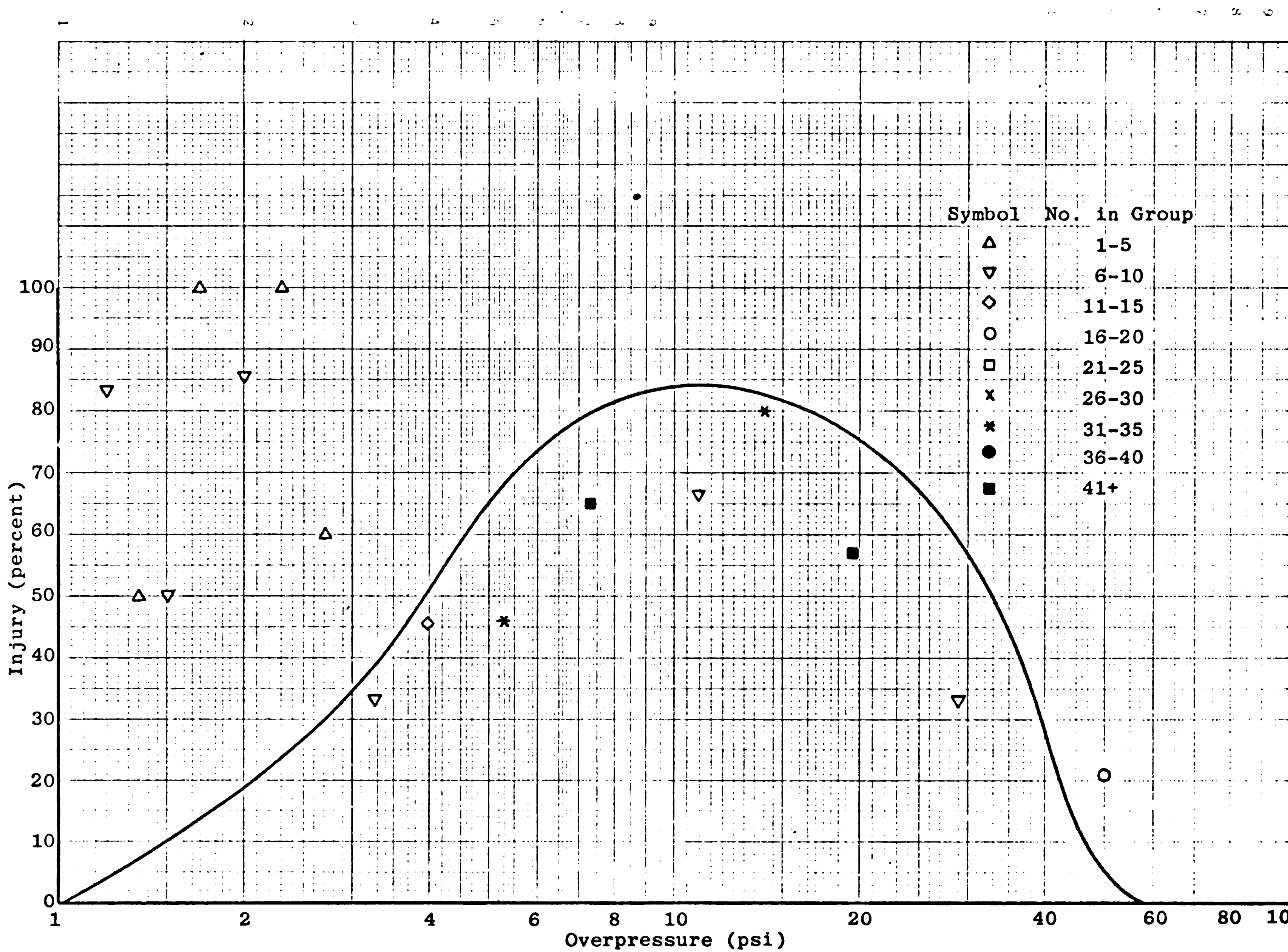

Figure 64. Texas City total injury curve for outside-shielded persons.

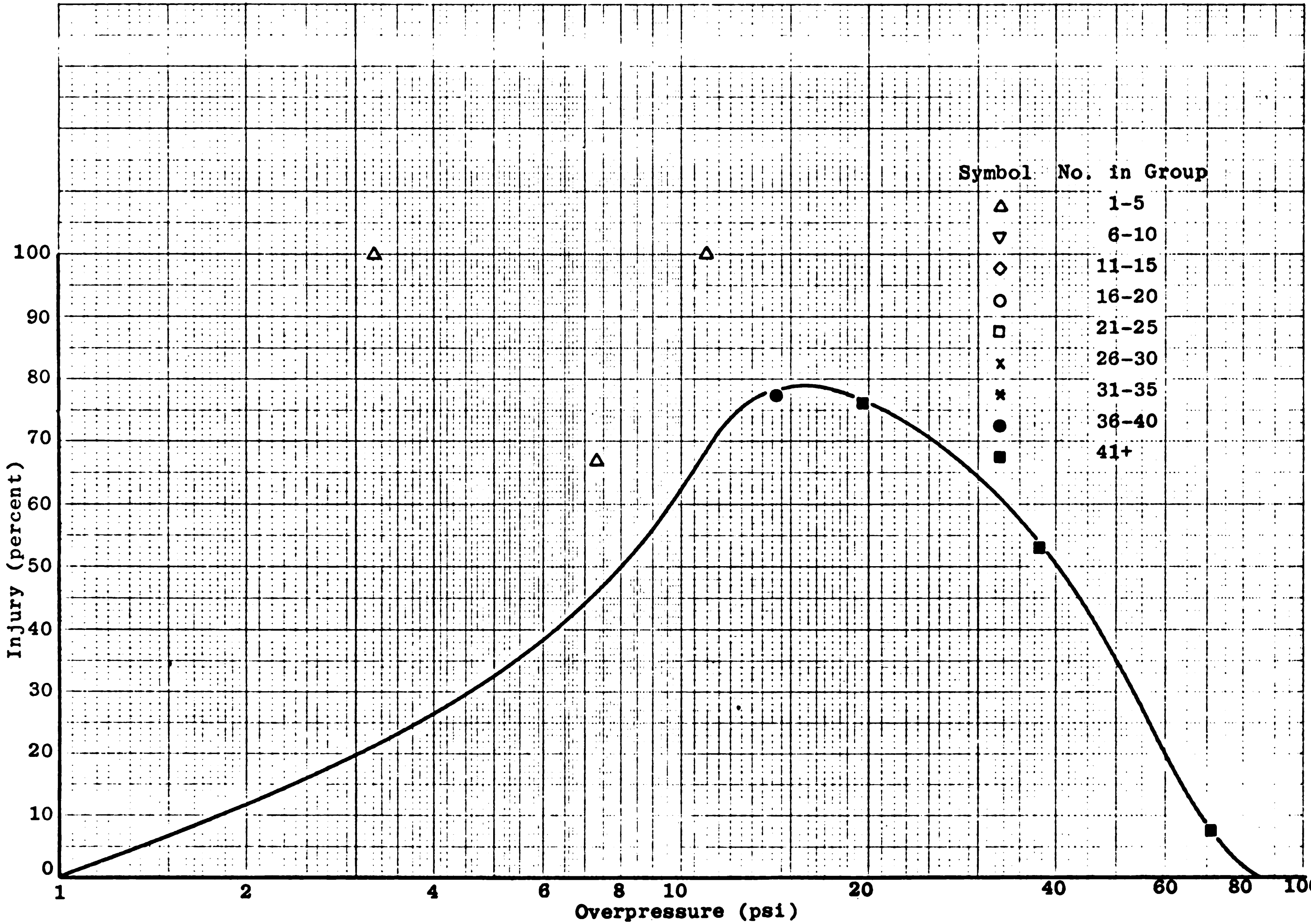

Figure 65. Texas City total injury curve for outside-unshielded persons.

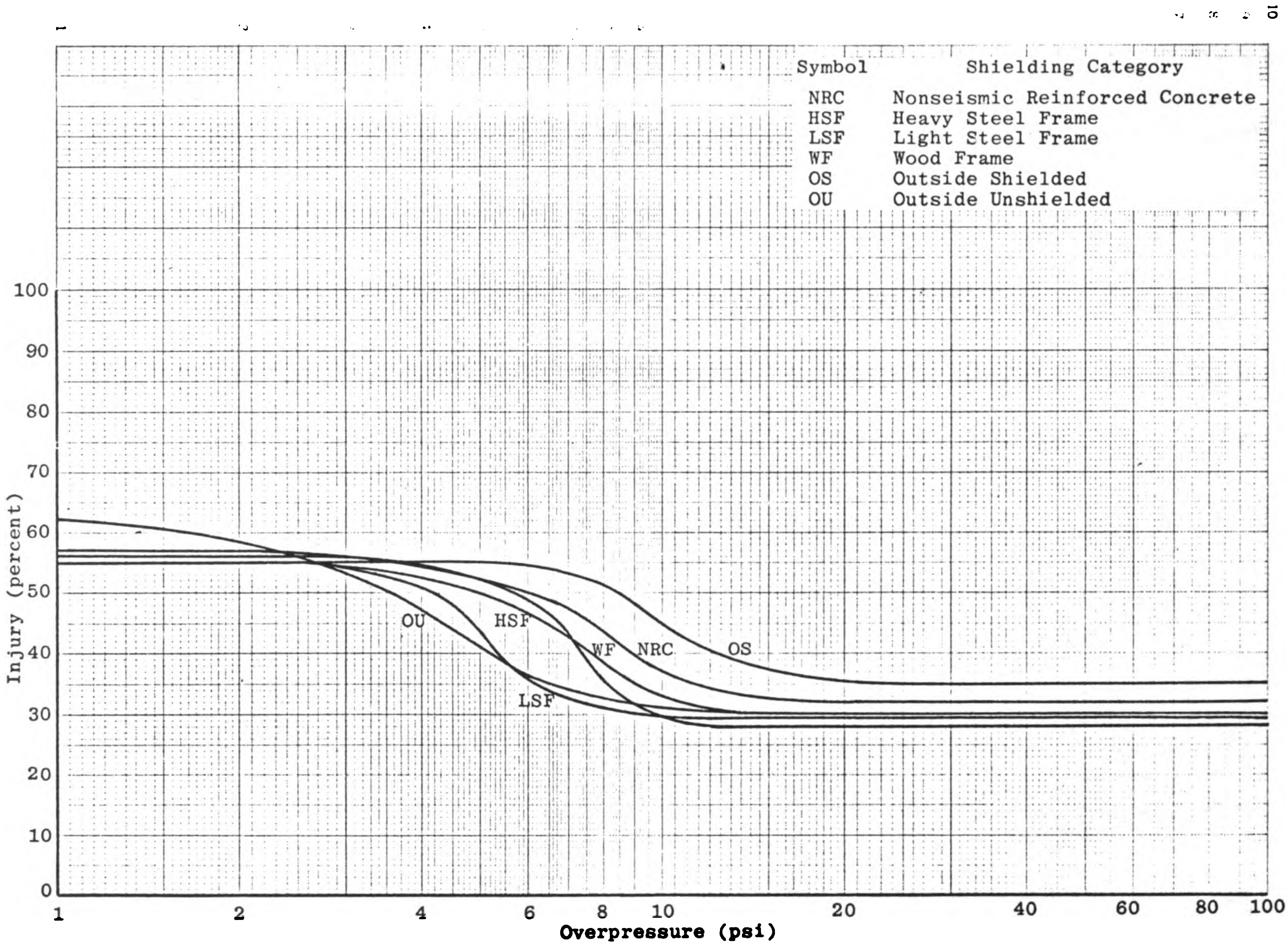

Figure 66. Moderate cuts, lacerations, and punctures by shielding category.

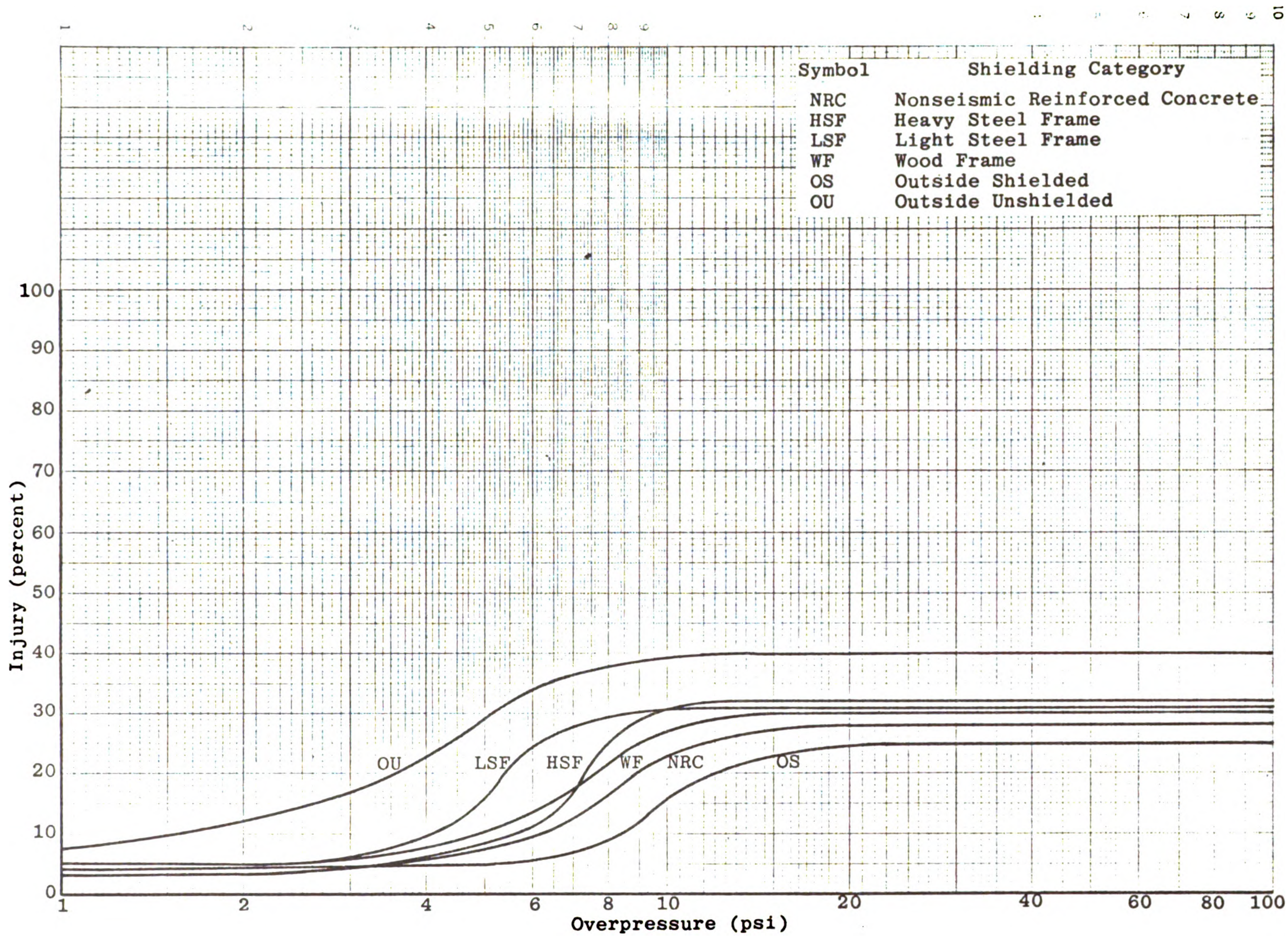

Figure 67. Severe cuts, lacerations, and punctures by shielding category.

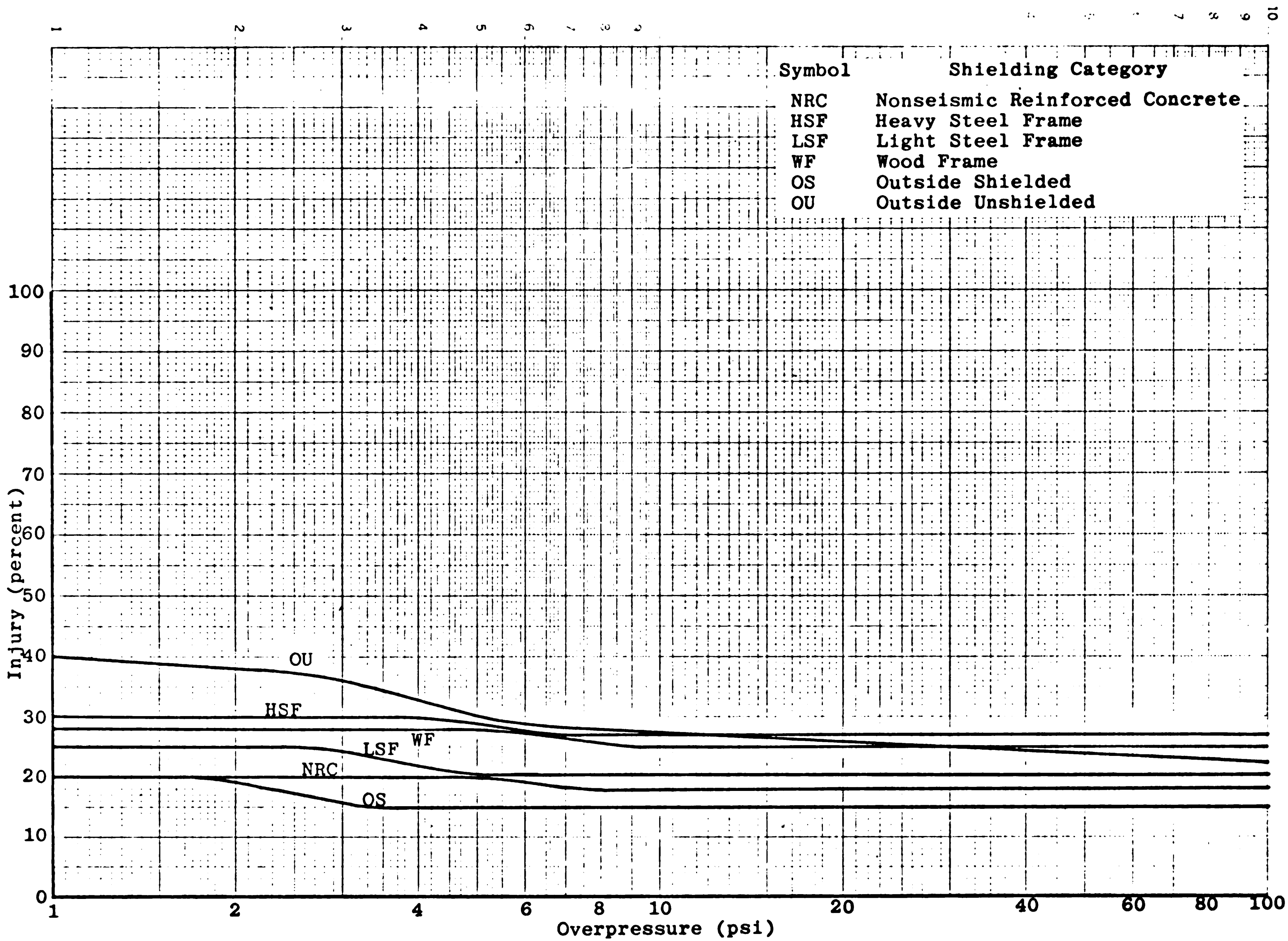

Figure 68. Moderate contusions and abrasions by shielding category.

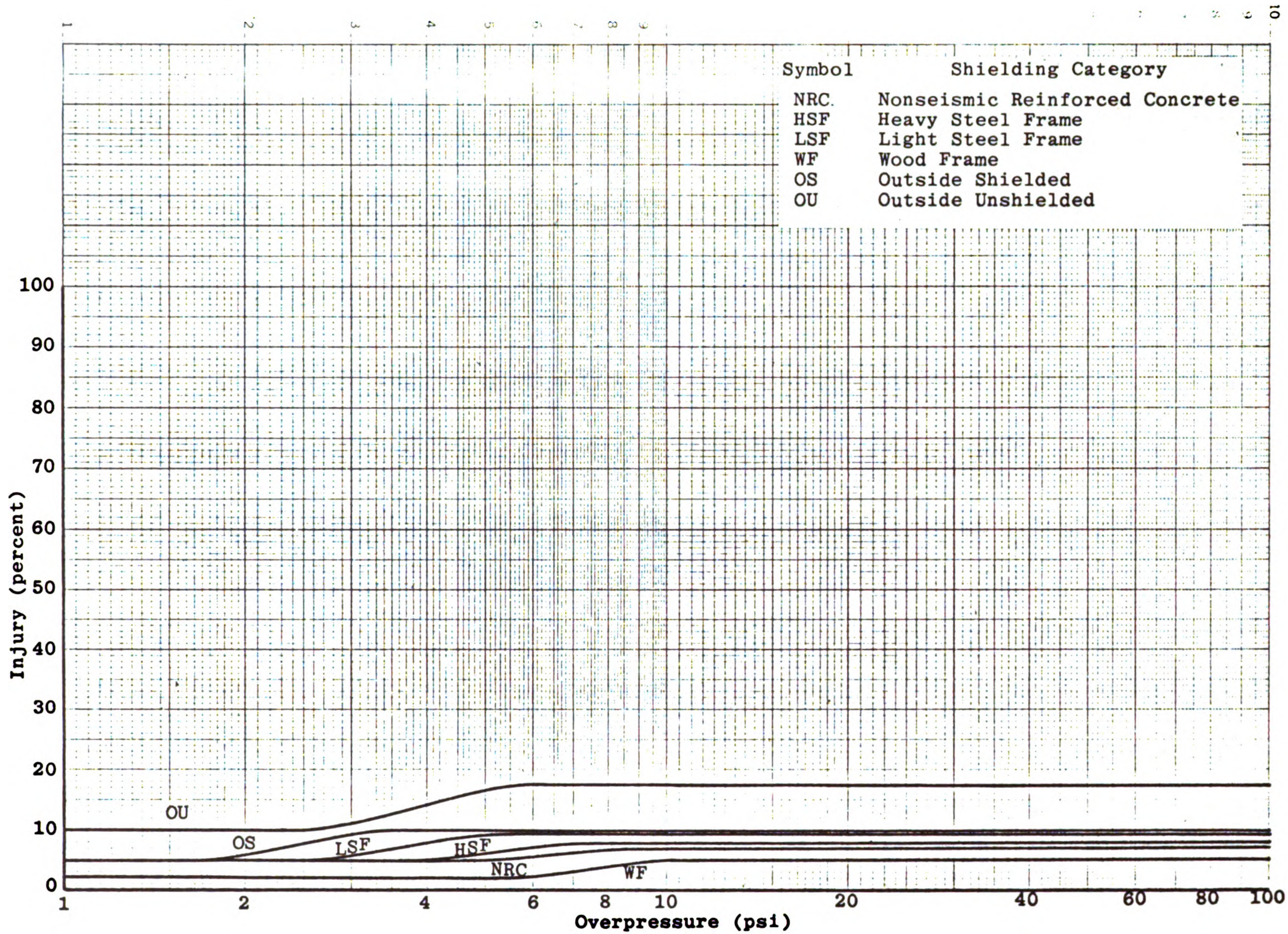

Figure 69. Severe contusions and abrasions by shielding category.

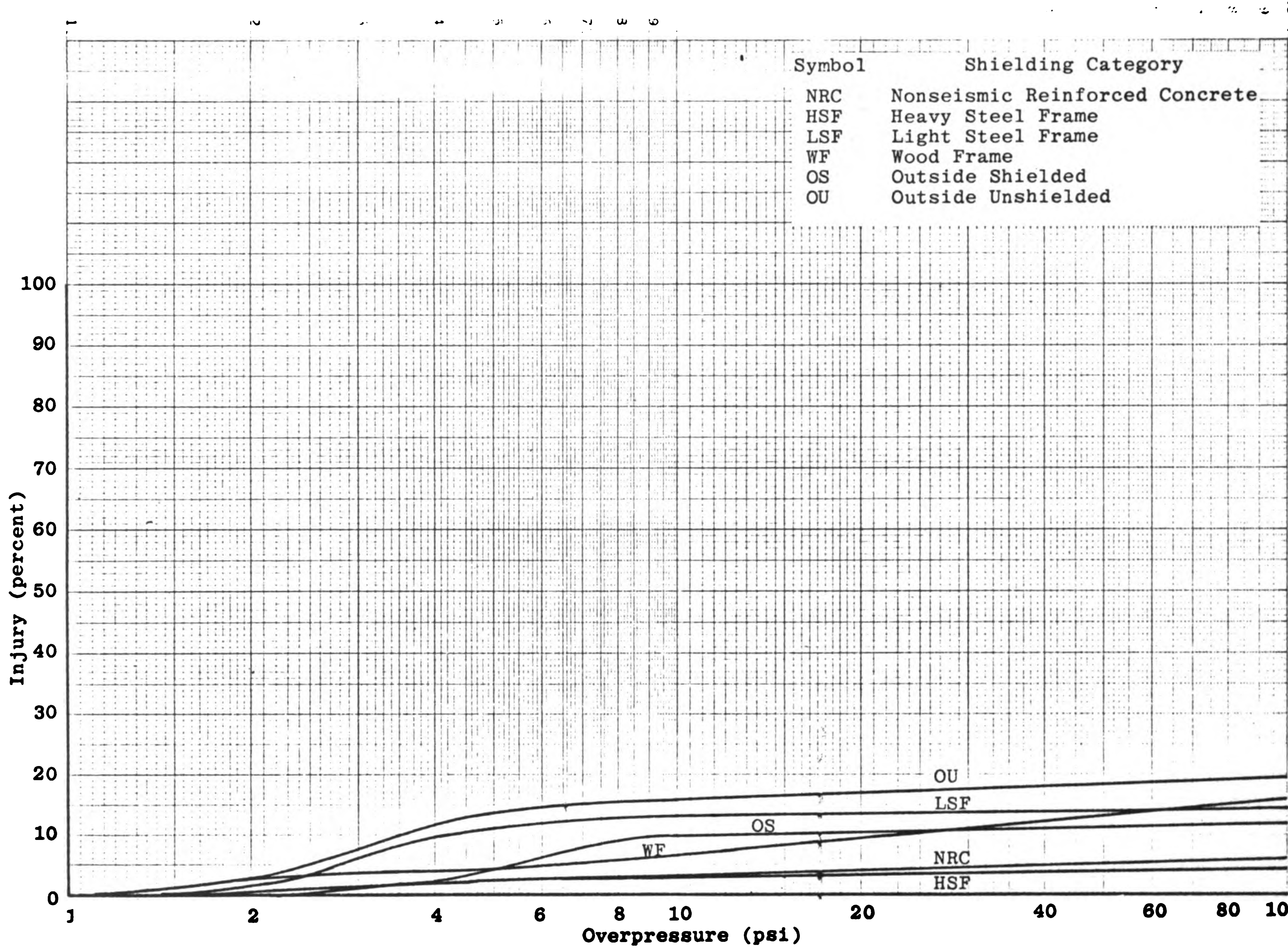

Figure 70. Moderate fractures by shielding category.

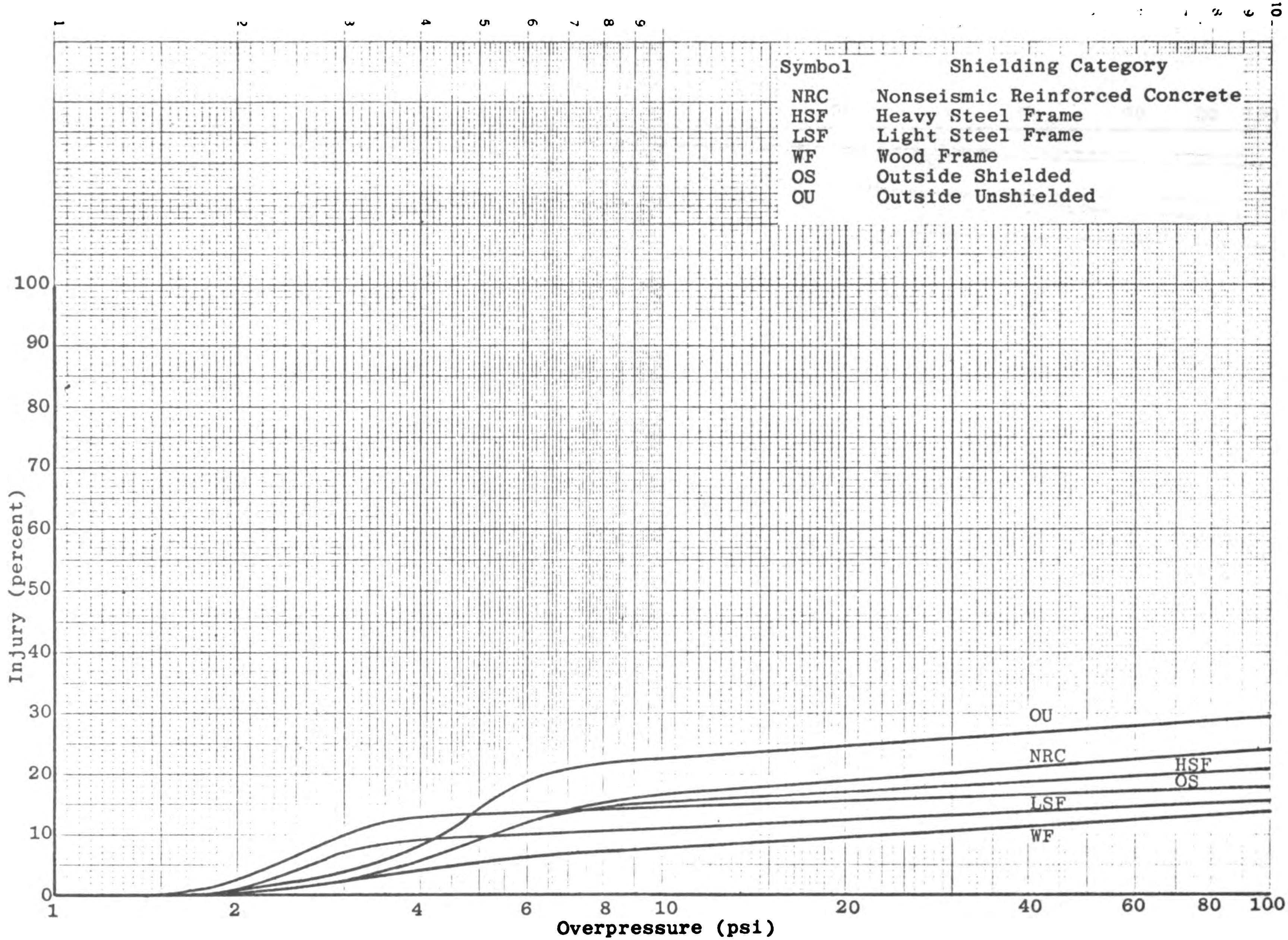

Figure 71. Severe fractures by shielding category.

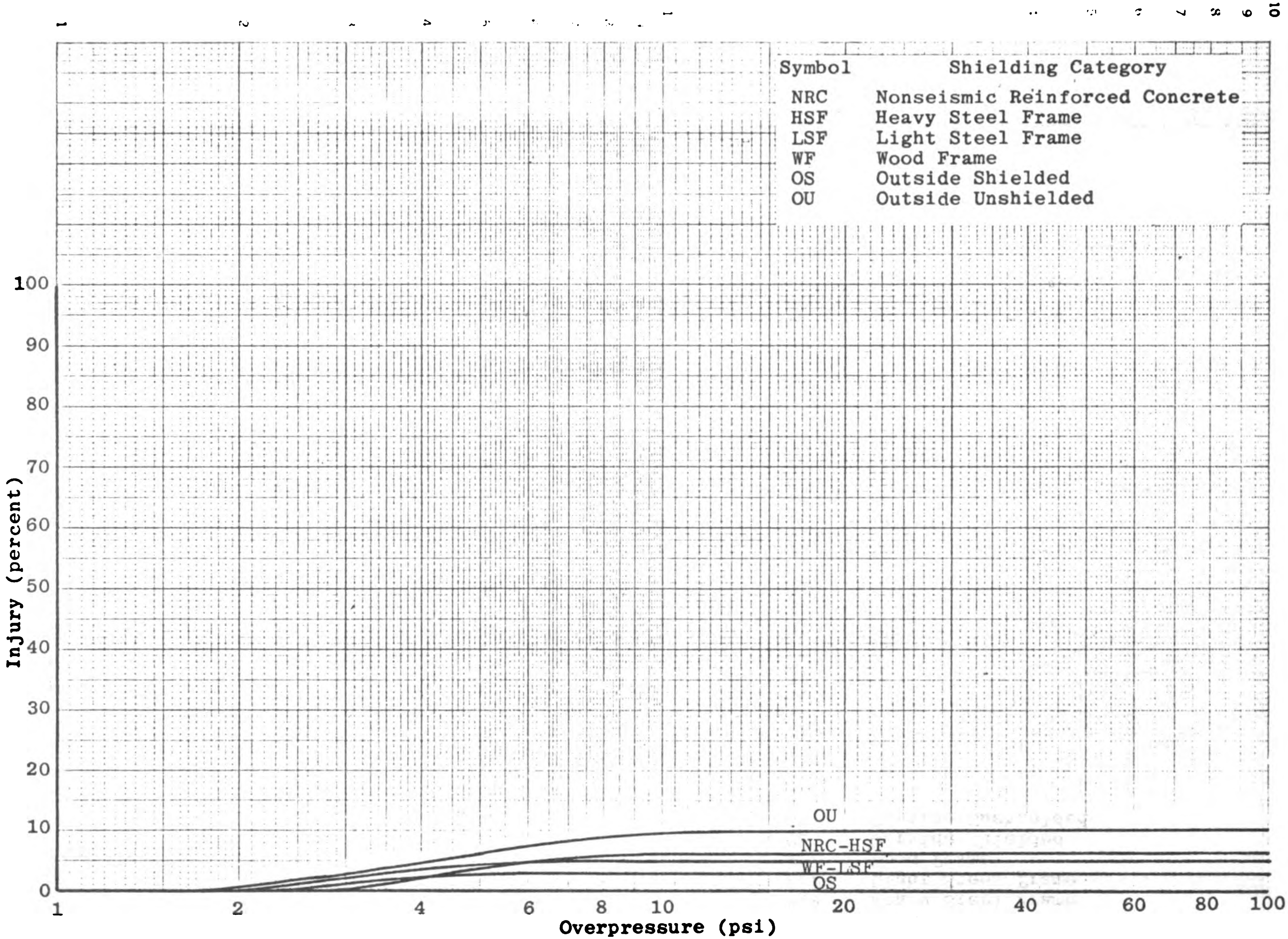

Figure 72. Skull fractures by shielding category.

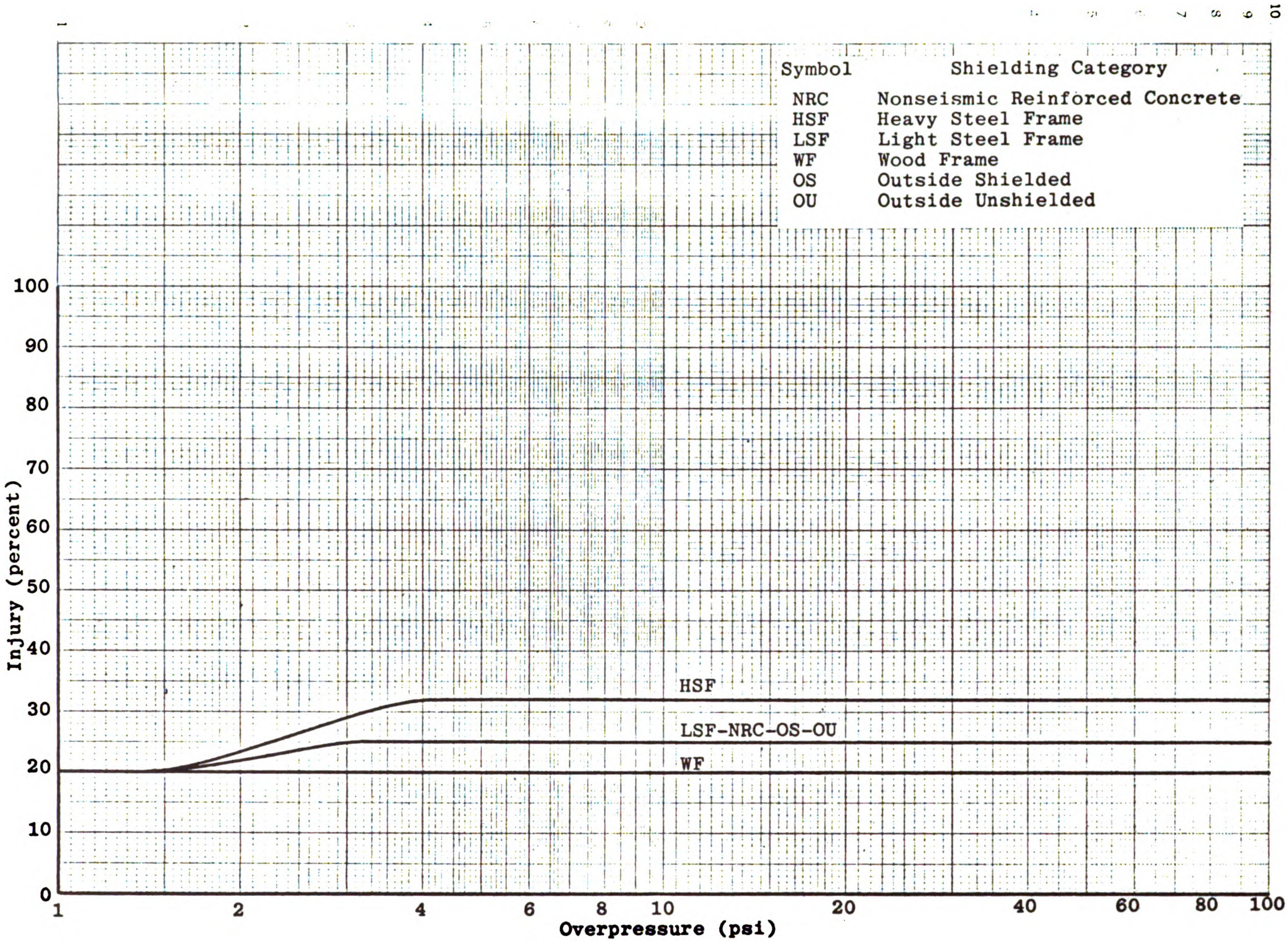

Figure 73. Impairment-of-consciousness injuries by shielding category.

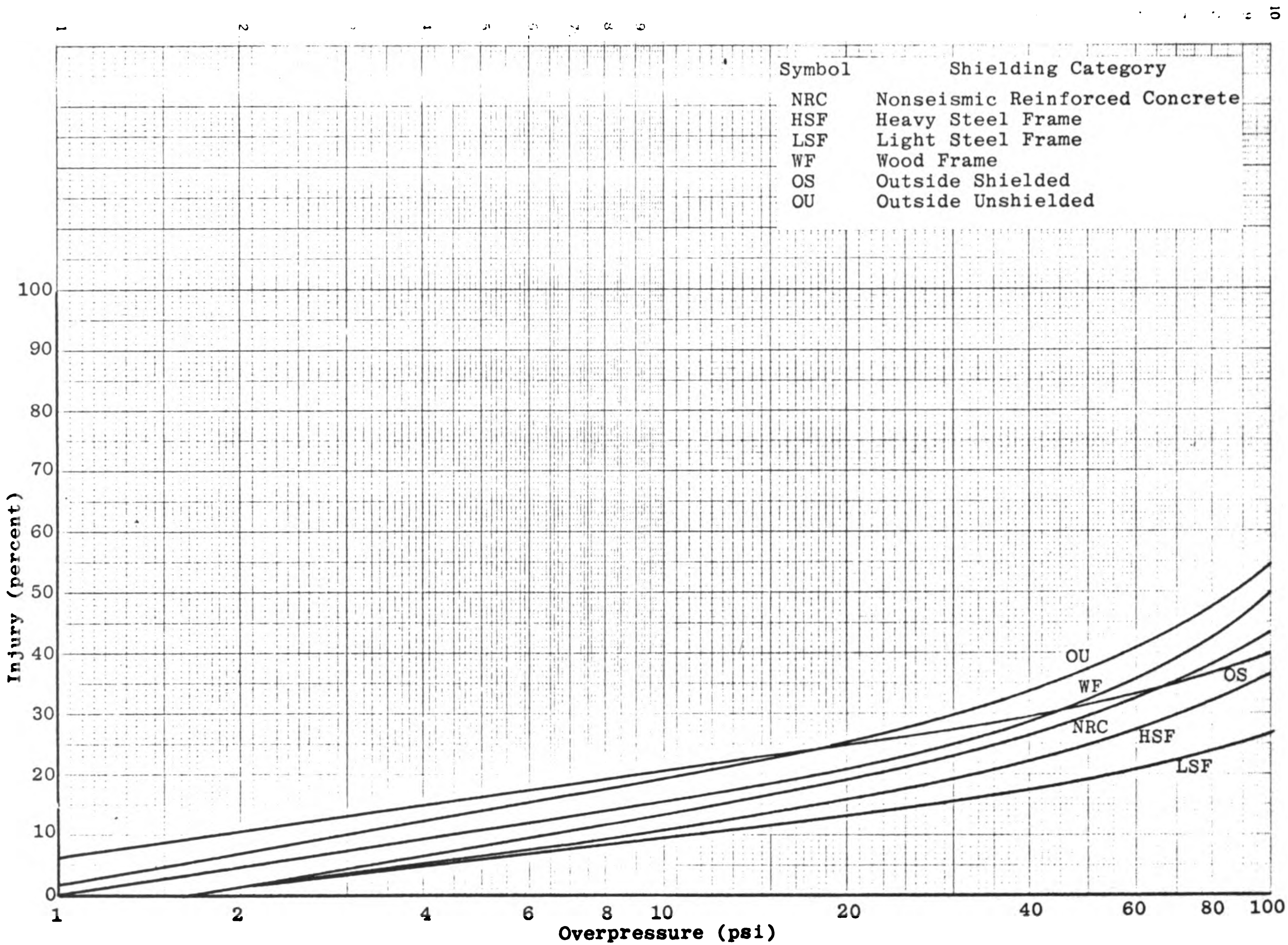

Figure 74. Ruptured-eardrum injuries by shielding category.

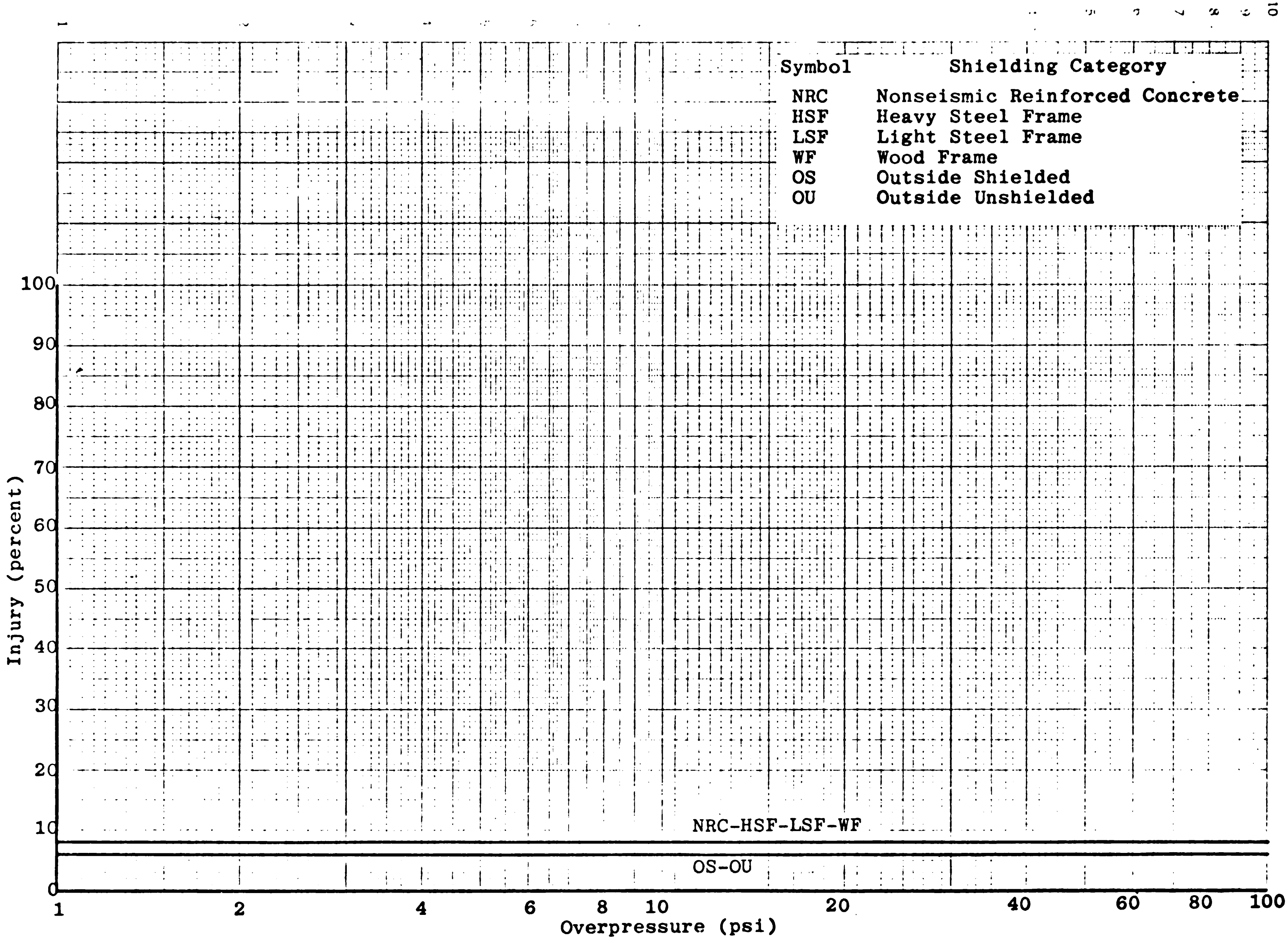

Figure 75. Eye injuries by shielding category.

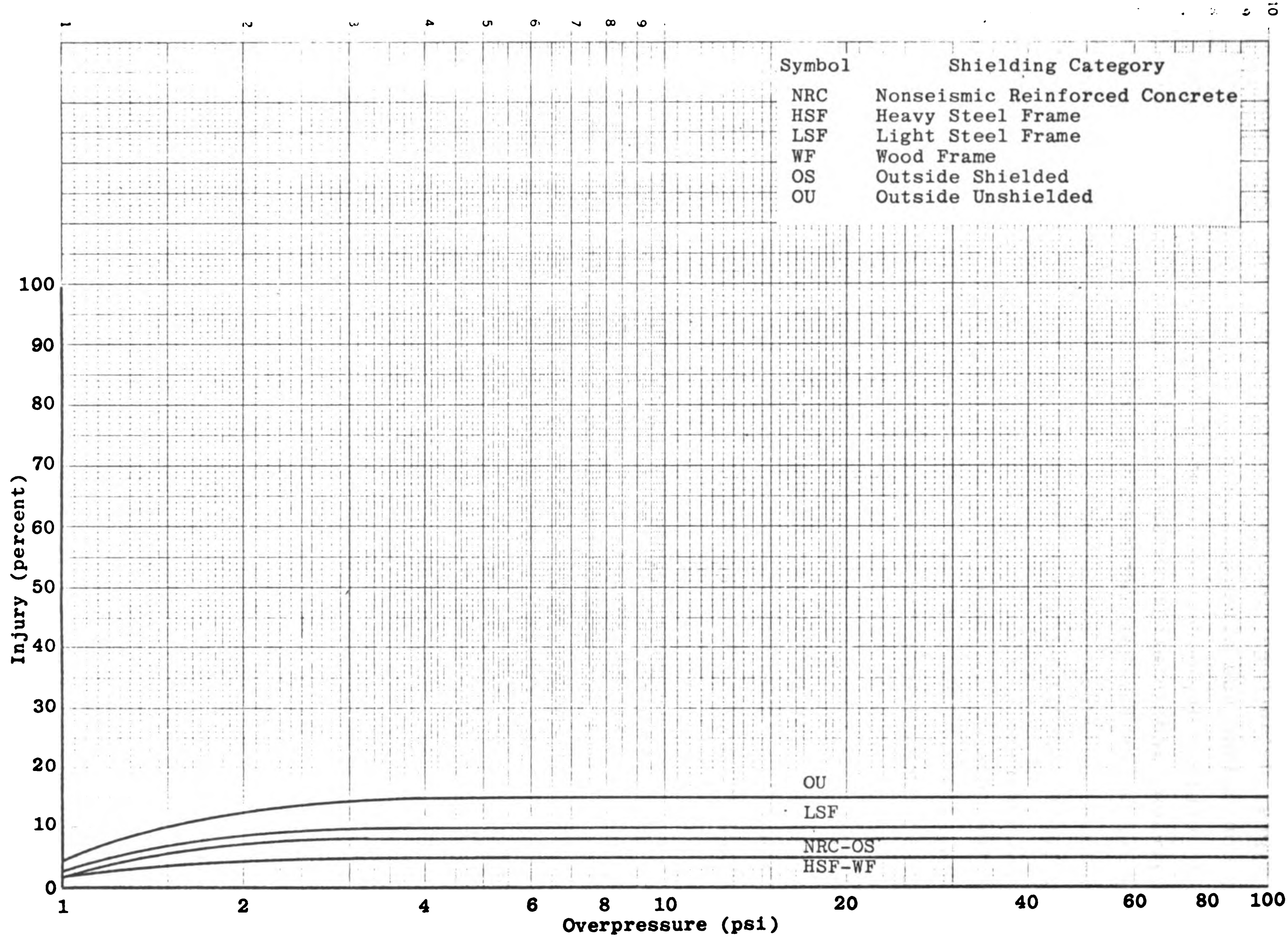

Figure 76. Internal injuries by shielding category.

each type of injury. The blast injuries were subdivided into eight types, defined as follows: cuts, lacerations, and punctures; contusions and abrasions; simple and compound fractures; skull fractures; impairment of consciousness; ruptured eardrums; eye injuries; and internal injuries. The first three of these injury types are further subdivided as to the severity of the injury (i.e., moderate and severe). The severity of these three injury types was determined on the basis of the overall injury state of the person rather than on the severity of the individual injury type present. These severity classifications were usually determined by the medical team preparing the case history for the person. It should be noted that the percentages given on these figures for types of blast injuries must be multiplied by the appropriate total blast injury percentage by shielding category (i.e., one of Figures 60 through 65) in a point-by-point fashion to obtain the overall injury percentage of that type applicable to the entire population at risk.

CHAPTER 4
CONCLUSIONS AND RECOMMENDATIONS

4-1 APPLICABILITY OF DATA

The blast data contained in this part are directly applicable only to blast casualty assessments, but may be used for nuclear weapons when suitably scaled to the appropriate yield. Applicable scaling techniques are discussed in Chapter IV and Appendix C of Reference 3. The principal reason for the direct applicability of these blast casualty data to nuclear casualty assessments is the relatively long positive phase duration of the shock wave. Another important feature of these data is the absence of initial-nuclear radiation and prompt-thermal effects. With proper scaling these data may be used in conjunction with the casualty data from Japan presented earlier in Part I. Because of the characteristics of the shock wave for this explosion, these casualty data should not be compared with casualty data derived from smaller yields for conventional high explosives (HE).

4-2 SALIENT FEATURES OF THE DATA

As noted above, relatively few persons were mortally injured (i.e., the total mortality and killed-immediately curves are essentially the same). Essentially, no one died from primary blast effects, as was also true in Japan, due to the almost complete destruction of the area where this type of injury would be prominent.

Recovery from the type of blast injuries received in Texas City was apparently less protracted due to the absence of the complicating influence of initial-nuclear and prompt-thermal injuries which are usually present with nuclear weapons. The data for injury severity and type of injury are probably more realistic than could be obtained from the Japanese data since the Texas City data were usually determined by physicians. The mobility (ambulatory and nonambulatory) data in Texas City are also probably more realistic than the Japanese data since extensive mass fires were not present in Texas City; however, all fires in the area were not completely extinguished until two days later (principally due to the nature of the fires and the lack of available fire fighting equipment after the first explosion).

4-3 RECOMMENDATIONS

The blast data from Texas City can be used to aid in the evaluation of blast casualties from nuclear weapons. This procedure is especially useful when various yields and burst conditions are of interest. It may be even more useful when unconventional nuclear weapons are being evaluated. These blast data are also very useful in isolating and evaluating the effectiveness of other nuclear weapon effects (initial-nuclear radiation and prompt-thermal radiation) in producing casualties. (This usage was especially valuable with respect to the Japanese data.)

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Medical Enclave, Ansari Nagar
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French Engineering Bureau
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